



## Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact [support@jstor.org](mailto:support@jstor.org).



J. Flaxman  
Inven. del.  
et sculp.

THREE  
LECTURES  
ON  
MUSCULAR MOTION,

Read before the  
ROYAL SOCIETY

In the Year MDCCXXXVIII:

As appointed by the WILL of Lady *SADLEIR*,  
pursuant to the Design of her first Husband

*WILLIAM CROONE*, M.D.

Fellow of the COLLEGE of PHYSICIANS,  
and of the ROYAL SOCIETY:

BEING A  
SUPPLEMENT  
TO THE

PHILOSOPHICAL TRANSACTIONS  
for that Year.

WHEREIN

The Elasticity of FLUIDS, and the immediate Cause of the Cohesion and Elasticity of SOLIDS, are proved by EXPERIMENTS, &c. and shewn to arise from the same Principle as Gravity: With a General Scheme of MUSCULAR MOTION, founded on ANATOMY, EXPERIMENTS, &c.

---

By ALEXANDER STUART, M.D. *Physician in Ordinary to her late Majesty Queen CAROLINE, Fellow of the College of PHYSICIANS, and of the ROYAL SOCIETY.*

---

*Non tam auctoritatis in disputando, quam rationis momenta quærenda.*  
Cic. de Nat. Deor. Lib. 1. cap. 5.

---

LONDON: Printed for T. WOODWARD, at the *Half-Moon*, between the *Temple-Gates* in *Fleetstreet*; and C. DAVIS, in *Pater-noster-Row*; Printers to the ROYAL SOCIETY. 1739.

## THE

## P R E F A C E.

*THE late learned and famous Dr. Croune having observed how much the knowledge of the animal oeconomy depends upon the doctrine of the nerves and muscles, and how far the rational practice of physic might be improved by a more perfect acquaintance with the animal oeconomy, did, for the encouragement of these studies, form a plan for instituting certain Lectures to be read on such subjects, in the Royal College of Physicians on the nerves and muscles, and in the Royal Society on muscular motion; which was left with his Widow, afterwards Lady Sadleir. In pursuance of which design she by her last will bequeathed a yearly revenue of about fifty pounds, out of her estate, to the said Royal College, in trust for the purposes abovementioned.*

*But an History of the lives of the several professors of Gresham College, where Dr. Croune was many years rhetoric professor, written by the learned and accurate Mr. Ward, his present successor in that province, being now in the press, we may expect farther particulars relating to this donation in that treatise, to which I must refer.*

*In the mean time, the Royal Society having a fifth part of the said revenue allotted to them by the will for that end, free from all charges and incumbrances,*



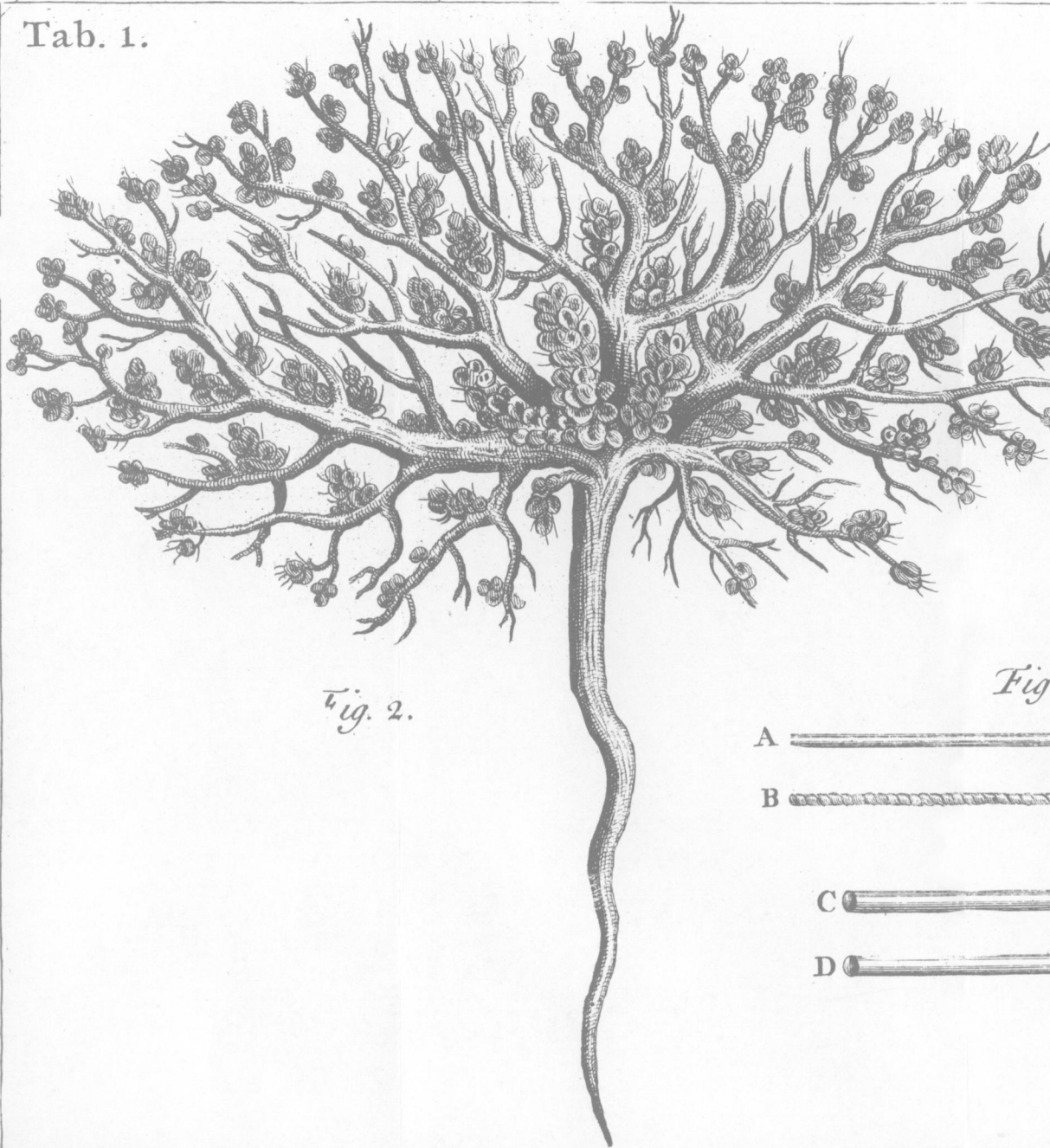
brances, excepting that of procuring a body for the use of these Lectures (which they are enabled to do by their charter) have undertaken, and intend to go on with a course of such Lectures on this foundation annually.

In this view the learned Sir Hans Sloane, president of that illustrious Society, a great encourager and promoter of natural knowledge, having done me the honour to nominate me to open these Lectures, I have endeavoured to the best of my power to answer the intention, as far as the limits of the three following discourses would permit; hoping the design may be better answered hereafter, when undertaken by some others of that learned body, of which there are many perfectly well qualified to make further discoveries and improvements in this abstruse and very useful part of natural philosophy.

It may be proper here to take notice, that by the constitution and custom of that excellent Society, every disquisition must either terminate in a mathematical demonstration, or be founded upon some one or more experiments, observations, or histories of facts, for a foundation of reasoning; and the conclusions drawn must appear to flow necessarily from such premisses, else they are accounted of small value. This method therefore sets all conclusions thus drawn at a great distance from guess, conjecture, mere speculation, or hypothesis; so that if no error be made in the application of them, they cannot fail to be useful in the several arts and sciences, to which they belong.

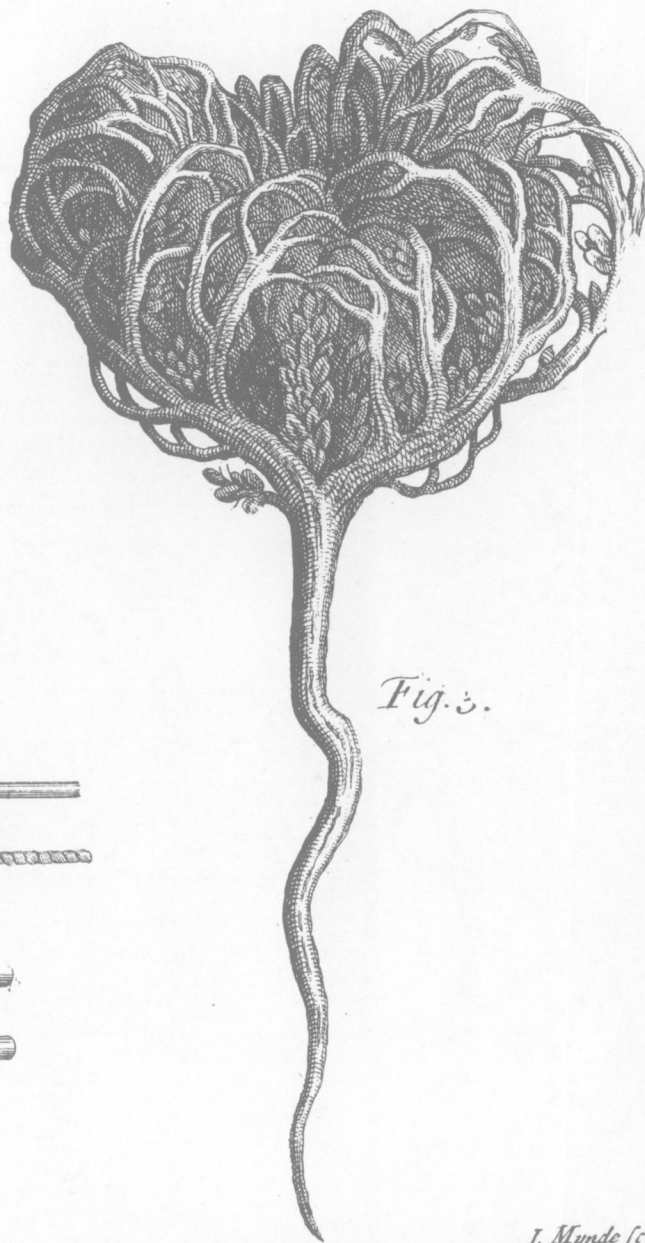
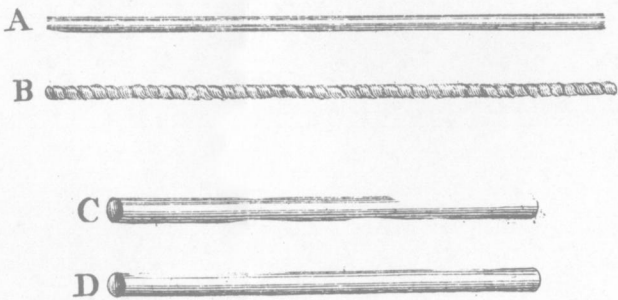
And this gives me a sufficient handle for wiping off an unjust aspersion thrown upon the labours of  
that

Tab. 1.





*Fig. 1.*



*Fig. 3.*

*J. Mynde sc.*

*that celebrated body, as if they were employed about useless speculations, or trifling amusements. But experience has shewn, how many useful arts and sciences have received considerable improvements by the discoveries of this, and other societies of the like kind, now established in several countries abroad, by their example; though many of the practisers perhaps may not know from whence those improvements had their first rise. An enumeration of particulars in proof of this would be too prolix, and improper for this place; especially as the most learned in all arts and sciences are not ignorant of this truth.*

*This method of disquisition therefore I have endeavoured to observe in the following Lectures, which contain several experiments, not made by any one before, that I know of. But how far the explanations of them are clear, the observations just, and the conclusions necessary and new, must be left to the judicious and candid reader.*

*Whatever is here advanced contrary to received opinions, or the positions of some great and learned men, being founded upon experiments, I hope may be held to consist with the great and just regard due to the memory of those, who by their incomparable works have so well deserved of the learned world, and of mankind in general; and who, I am persuaded, were such lovers of truth themselves, that they would have been pleased with its appearance, whencesoever it had arisen.*

*In these Lectures the following propositions are offered to be proved by experiments, and confirmed by observations of facts.*

1. *That fluids are elastic ; which has hitherto been universally denied of all of them, excepting the air.*

2. *That the immediate cause of the various degrees of cohesion and elasticity of solids, which has lain in obscurity, is in the fluids they contain.*

3. *That the principle of gravity, cohesion, elasticity, and hydrostatics, is one and the same.*

4. *That next to primary immaterial impulse, centripetal power, or central attraction, appears to be the natural principle not only of muscular motion, that is of all the motions in the animal œconomy, but also of all other motions in the universe.*

5. *That there is no natural centrifugal power in matter, or any such principle of repulse, as has been generally supposed.*

6. *That repulse, in all the phenomena here related, appears to be solely an effect of central attraction, and by analogy is probably the same throughout all nature.*

7. *That the arteries are elastic ; which has been but imperfectly known, and very little regarded in the phenomena of the animal œconomy, in which their elasticity bears a very considerable share.*

8. *That the veins are also elastic, which has been intirely overlooked.*

9. *That the blood is an elastic fluid, which has not been imagined.*

10. *That the nerves are not elastic, as has been generally advanced and believed.*

*If these propositions be sufficiently proved here, they are to make the chief hinges of the preliminary arguments, leading to the various conclusions contained*

## P R E F A C E.

*tained in an abstract of a general scheme of muscular motion; which I submit to the test of an application to all parts of the animal oeconomy, by which, I hope, it may appear to have a real foundation in nature, which no mere hypothesis can have.*

*As I find no author to produce in confirmation of several things here advanced; I have no inclination to quote or refute such, as have thought differently on these subjects: for every attempt towards the discovery of truth, including a good will towards mankind, has its merit, and deserves praise, though it should not prove successful; but contention about it often leads insensibly to some breach of humanity, which the love of truth itself can never justify. And therefore I choose rather to depend upon the force of this maxim; that a discovery or demonstration of truth, if it can be attained to, is the best refutation of error.*

*I am aware of the danger of drawing general conclusions from too scanty premises, or too few experiments; which I have endeavoured to avoid as far as possible; and, I hope, as far as is necessary, in an argument of this kind. For we are to consider, that though the method by induction be the most demonstrative, and therefore the most eligible; yet no number of experiments or effects, though ever so great, would be sufficient for establishing a general conclusion concerning the cause, such as might be said to be drawn from a complete induction of particular effects; which in nature are so exceeding numerous, that an indefinite number of them must be always out of our reach. And therefore a few experiments or effects clearly*

*ex-*

*explained, and supported by the analogy of nature (which in all its operations is constantly similar to itself) are sufficient for the purpose of a demonstration a posteriori, or from the effects to the cause; until some plain experiment, and well understood, contrary to the former, can be produced, and shewn to arise from a different or contrary cause. But this I take to be impossible in the case before us; since nature can admit of no direct contrariety or inconsistency, with regard to its principles, which are few and constant, and their laws of action always the same.*

*There is indeed such a surprising variety of seemingly contrary appearances or phenomena of nature, as would deter one from drawing a general conclusion, with regard to the principles from whence they proceed; was it not observable, that this variety of phenomena does not arise from a variety of principles, or different laws of action, these being (as I said before) very few and always the same; but evidently from a numberless variety of circumstances, and degrees of force, not rightly considered, or not well understood, by the spectators. This will appear by the reconciliation of several such contrary phenomena cited in the following Lectures, arising from the very same principles and laws of motion.*

*And as this may not be so obvious to the generality, as it is to the learned reader, it will be of use to add, that the danger of drawing general conclusions in natural philosophy, and physical disquisitions, lies not in arguments a posteriori, or in the analytic way, as here, from the effect to the cause :  
but*

*but in such as are carried on from the cause to the effect in the synthetic and hypothetic way; that is, when from an identity, parity, or similitude of the cause, we would infer universally an identity, parity, or similitude of the effects, which must be often, if not always, a fallacious method, and has been the source of manifold errors. For the same cause acting by one and the same power, in the same degree, and according to the same laws, is often found to produce not only different, but even contrary effects, according to the specific differences of the subjects acted upon. I choose a very familiar instance for the explanation of this. The sun acting by its rays, or the fire by heat, melts wax; yet by the same power, acting in the same degree and manner, they do the very reverse in hardening clay.*

*Thus the most perfect knowledge of the power of the sun, or of heat, as a cause, could not lead us with certainty, a priori, to any one effect; much less to the variety of its effects, which may be innumerable, vastly different, and even contrary. There is therefore an irremediable insufficiency in this method of argument a priori, or in the synthetic way, even when the cause is real and known. But if to this defect we add an hypothesis or supposition of a cause or principle, which is not in nature, but only in the imagination, then no real effect can possibly proceed from it; and every particular, as well as every general conclusion, in the whole scheme may be false.*

*And it is this method of disquisition a priori, and by hypotheses of imaginary principles and causes,*  
in-



*andulged with so much liberty in former ages, that has laid physic, with other parts of natural philosophy, under the disreputation of conjectural sciences; though when pursued upon facts and experiments, that is a posteriori, the conclusions properly drawn appear to be as demonstrative, as those of any other science whatever. The progress in this method indeed is slow, but the footing is sure; whereas in the other way the advances are quick and extensive, but upon infirm ground.*

*Thus in the instances above assigned, if we suppose or assume nothing, but take the facts, effects, or phænomena, as we find them, and consider the apparent sensible qualities of the subjects acted upon, and compare them; we have yet made no mistake. Then ascending to the cause, we find it to be one and the same, acting by the same sensible power; in which also we cannot be deceived. Therefore the conclusion is plain and necessary, that whatever diversity or contrariety appears in these effects, does not arise from a diversity in the cause, but possibly from the different natures and circumstances of the subjects acted upon. And these being duly considered, one appears to be a mixture of water and earth, the other of oily and resinous substances. And experience, which has shewn us, that the heat of the sun or of fire can make water to evaporate, warrants the conclusion; that it can in the same manner agitate the watery fluids in the clay, and make them to evaporate, and leave the earthy mass more solid than before. But experience also shews, that the same degree of heat cannot evaporate oil or resinous substances, and therefore cannot eva-*  
*porate*

*porate the oily or resinous particles of the wax ; though it may easily separate and agitate them to a fluidity, as a greater degree of it does the most solid metalline substances.*

*Thus by begining at the effects, and considering the nature or qualities of the subjects, and their differences, and ascending at last to the cause or causes, these and such like different or contrary phænomena may be solved without error or hypothesis. And if we go no farther, than an exact analogy of the subjects and circumstances will carry us, the conclusion will be universally true, with respect to the identity of the cause producing these effects ; let the effects themselves be ever so different or contrary.*

*Therefore though no general conclusion can be drawn with certainty a priori, or from the cause to the effect, in the synthetic way, whether with or without an hypothesis ; yet general conclusions may be drawn by analysis, or a posteriori, upon facts and experiments, without the necessity of any hypothesis ; and such conclusions, if they have been carefully managed, will appear to be certain and demonstrative.*

*Thus much I think necessary to be said for recommending the analytic method of disquisition in all physical essays or inquiries, and in vindication of physic and natural philosophy, as now generally cultivated ; and also to set these two different methods of investigation in a true light, in order to take off the prejudices, which may lie against general conclusions, when they can be attained to in the analytic form of argument. Which is what I have endeavoured to observe in all parts of these*

Lectures, by laying the foundation in experiments and observations of facts considered and compared, and solving the plain phænomena at last without an hypothesis by a real and known principle in nature, as their universal cause acting by the known laws of mechanics and hydrostatics; the principle itself and these laws being as real, constant, and unchangeable in the present constitution of nature, as the principles of pure mathematics themselves.

*This method was first strongly recommended and illustrated by that incomparable genius the Lord Verulam, who calls it his Novum Organum, his New Method by Induction, The Art of investigating Forms or Principles, Philosophical Algebra, &c. And it has since been successfully employed for unfolding several of the most mysterious phænomena of nature by the great Sir Isaac Newton, Mr. Boyle, Dr. Boerhaave, and other learned men and societies, the famous reformers of natural philosophy and physic in this and the last century.*

N. B. The Doctor's Name is found written by himself sometimes *Croone*, and at other times *Croune*. See his *Life*, in Mr. *Ward's Lives of the Professors of Gresham-College*.

---

---

## L E C T U R E I.

**T**HE design of the learned Dr. *Croone* in forming the plan of these *Lectures on Muscular Motion* seems to have been, not only for the encouraging and promoting the investigation of the muscular structure, with the cause and manner of muscular motion in general; but also for carrying on a more accurate anatomical discovery of the peculiar structure, with the manner of motion, and use of each particular muscle of the animal œconomy, in the several classes of the natural, vital, and animal functions: for in all these this learned and ingenious person well saw, that there was a large field open for improvement.

In this view the subject appears to be so copious, that three or four Lectures annually will not be sufficient to exhaust it in many years.

When the Society shall think fit to make use of the Privilege granted them by their Charter, for obtaining a body, the purpose of these Lectures may be much better answered, than it can be at present without one.

In the mean time, this laudable design may, I conceive, be best answered, and most to the satisfaction of the curious, by laying a foundation for the future Lectures, in the few Experiments and Observations following, which I shall take leave to offer in these first discourses.

## E X P E R I M E N T S.

I. *The elasticity of the blood-vessels, and non-elasticity of the nerves, demonstrated on a nerve, artery, and vein of an human body cut out, and the degree of the elasticity measured.*

II. *The distribution of the nerves, arteries, and veins, to the antagonist muscles of the arm of an human body, shewn in an anatomical Preparation; for demonstrating the necessity of such a distribution towards the performance of muscular motion.*

III. *In the Air-pump, on the jugular vein of a Calf; to shew that there is air in the blood.*

This Experiment stands in the Minutes of the *Royal Society*, as first performed by me, about 17 or 18 years ago; and is now only repeated on occasion of these Lectures.

IV. *Upon an human Artery, and the Rose of Jericho; to shew that the elasticity of solids arises from the fluids they imbibe or contain.*

V. *On a Frog; to shew the existence of a fluid in the nerves, and that Muscular Motion is begun by an impulse on it through the nerves into the muscles.*

Upon these Experiments, anatomical Preparations, and Observations made upon them, the doctrine of Elasticity, and of Muscular Motion, chiefly depends; and none of them have been made by any one before, nor are they extant in any author, that I know of.

VI. *On Water, Oil, and Mercury in the Air-pump; to prove the elasticity of fluids.*

This Experiment, if it ever was made before, was at least never yet applied to prove the elasticity of fluids,

fluids, and shew the immediate cause of elasticity, and cohesion in solids.

*The Manner, Explanation, and Use of the first Experiment.*

1. The elasticity of the blood-vessels, and non-elasticity of the nerves, will appear to any, who are disposed to make this Experiment, as I have done, by laying a piece of twine, about four inches in length, parallel to the nerve, artery, and vein of the inside of the thigh, in an human subject; which being tied together above and below, so soon as they are cut out of the body, and laid on a board, the artery and vein will be seen to contract equally, to the loss of  $\frac{2}{3}$  parts of the length, which they had in the body before excision; as appears in those in fig. 1. tab. 1. the nerve continuing of the same length with the twine, as in the body.

2. In Dogs the elasticity is greater, to the loss of  $\frac{3}{4}$  parts of the length they had before excision; and as this elasticity seems to differ in different species of animals, so it may vary in the individuals of the same species, and in the same individual in different stages of life, or degrees of health.

3. The use of this Experiment is not barely to shew, that the blood-vessels are elastic; for every one who knows, that the artery is dilated in its diastole, and contracted in its systole, knows it therefore to be elastic in that sense; and every one, who has performed the ligature on the artery after amputation, knows that it shrinks or shortens its axis, and therefore is also elastic in that sense. But though this be known, yet the measure or degree of the elasticity of

an artery has not, that I know of, been taken notice of by any body. And, *secondly*, as the vein has no pulsation, and is never designedly tied in an amputation, its elasticity has been overlooked; though it be equal to that of an artery in degree, but not in *momentum*, its coats being thinner than those of the artery. *Thirdly*, The non-elasticity of the nerves has not been so much as once named by any Author, as I remember, before the publication of my inaugural *Theses* at *Leyden*, *Ann.* 1711. where it is remarked, and since that time by Dr. *Boerhaave* only, in the subsequent Edition of his *Institutions*, *Ann.* 1713, and the two following Editions. But on the contrary, all the Authors on Muscular Motion, that have come to my hands, as well as those who have written of the Theory and Practice of Physic, have supposed and ascribed elasticity to the nerves.

4. The Experiment therefore is so far useful, as it discovers some essential properties of these essential parts, which were not known before; and clears up some mistakes, that passed for fundamental truths, relating to the nerves and veins, in explaining most parts of the animal œconomy, as well as muscular motion in general.

5. And it is further very remarkable, that though the elasticity of the artery has always been known, and indeed obvious in the pulsation: yet Authors have been constantly so full of the elasticity of the nerves, in explaining not only muscular motion, but also several other parts of the animal œconomy, and even in accounting for the symptoms of various diseases; that they have taken no other notice of the elasticity of the arteries, than solely as it propels the blood in  
the

the circulation through them : and even in that, by their doctrine it has been allowed but a very small share ; and by most of them no share at all.

6. And it may not be amiss to observe, that this Experiment was never made by any, that I know of, till the said year 1711 ; and afterwards, in the year 1735, when I first shewed it to this Society. And further, tho' it appears simple and easy to be made, yet it is of the utmost consequence in all parts of the animal œconomy : for as all parts of the animal body are entirely composed of nerves, arteries and veins, (excepting the hardest fibres of the bones, which also are nourished by them) it is certain, that all the animal functions depend upon the qualities and contents of these three parts. Therefore this Experiment, as it demonstrates the qualities, and degrees of the qualities, of each of these, gives us the qualities of the solids in all parts of the body ; and therefore opens at least one door towards the explanation of all the animal functions, as far as they depend upon the solids.

### *Explanation and Uses of Experiment II.*

1. The next thing which we are to take notice of, is the form or manner of the distribution of these three essential parts to the various organs at their extremities ; for upon this distribution, and the structure of the organs, which they lead to, depends the whole variety of the functions, whether natural, vital or animal.

2. The cause, manner, and effect of voluntary muscular motion, being a point that the Founder of these Lectures had chiefly in view, it was necessary  
to



to observe the manner, or order of distribution of these essential parts to the organs of voluntary motion, the muscles.

3. For this purpose therefore I exhibited this anatomical preparation, not extant before in any Author, and, so far as I know, not hitherto attempted by any one; namely, the antagonist muscles of an human arm, with all the nerves, arteries, and veins leading to them, intire, as they appear in the subject itself; and likewise laid before you a very accurate draught of them, wherein the arteries are marked red, the veins blue, and the nerves white, as in fig. I. tab. 2.

4. The uses of this preparation are various. *1<sup>st</sup>*. As it shews that there is no communication between the antagonist muscles by their nerves, each having a peculiar trunk or trunks and branches of nerves distributed to it, distinct from those of its antagonist; by which the mind has a distinct power over each, and may at pleasure act upon either, without acting upon the other: for if both were equally acted upon at the same time, no motion, but a rigidity and immobility, would ensue. *2<sup>dly</sup>*. This preparation shews that the antagonist muscles have a communication with one another, by the intervention of their blood-vessels, as there appears to be one trunk of an artery, and one trunk of a vein, common to both.

5. This seems also to be absolutely necessary towards voluntary motion, and the power and energy of it; to wit, that the acting muscle may have a greater derivation of blood into it from the common trunk  
of

of the artery, than its antagonist, which is at that time to remain passive.

6. Both these very essential parts of voluntary muscular motion must have remained in the dark, without such an anatomical preparation. The mechanical cause and manner of this derivation of an accessory quantity of blood to the acting muscles, depends upon this distribution of the vessels, and the mechanism of the muscular structure, which shall be shewn in the course of the following Lectures; wherein it will appear, that the antagonist muscles of voluntary motion are like two antagonist scales of a balance; and that it is in the power of the mind, by means of this, and other parts of the muscular mechanism, not only to throw in a greater weight at pleasure into either scale, but further to throw the weight taken from the one into the opposite scale, by which the *momentum* is doubled on the side, on which the mind determines to act.

*The Manner, Explanation and Use of Experiment III.*

1. This Experiment is performed by laying bare the jugular vein of a Calf, before it be killed, and separating it carefully from adhesions; which is then to be tied with a close ligature, first below near the *thorax*, and then in the same manner near the head, at the distance of three or four inches from the former ligature, so as that the intermediate segment of the vein full of blood between the ligatures may be cut off beyond the ligatures.

2. This

## Lect. I.

## [ viii ]

2. This segment of the vein, turgid with blood, should be immediately put into a vessel full of luke-warm or blood-warm water, to keep the blood from coagulating within it, which would happen in a few minutes, if it was exposed to the cold air.

3. The vein being taken out of the warm water, is to be tied to a small square paste-board frame, and made fast over the mouth of a wine or jelly glass, or any such vessel tapering towards the bottom, and put into the recipient of an air-pump, which being exhausted, the vein is to be opened with a lancet, fixed at the end of a wire, passing through a collar of leathers.

4. The consequence of this is, that the blood, which runs out of the vein into the vessel set underneath, will be immediately and totally raised up in air-bubbles, and thrown out of the vessel upon the plate of the pump, by the force of the air which it contained, equally distributed through the whole mass.

5. By which it appears, that the blood is greatly stored with air, as was to be shewn.

### *Remarks on this Experiment.*

*Obs.* I. § I. It is remarkable in the *apparatus* to this Experiment, that the heat of luke-warm water, which is nearly the same with the heat of incubation, keeps the blood in the vein in a state of fluidity for some hours; and I believe it might be kept in that state much longer, which deserves a trial; this being, as I imagine, the standard degree of heat in all such outward applications, as are intended to dissolve, attenuate, and discuss stagnating animal fluids, or disobstruct the vessels: intentions which are rather hindered

hindered than promoted by too hot baths or fomentations, in which the mistaken standard degree is as hot as the patient can bear it, instead of what he could call a comfortable warmth, and would be the useful measure for him. This degree of heat would indeed be different to different persons; but every one would have the due degree suited to his temperament, constitution, and feeling, in which he could not be deceived, being himself the best judge. Nay even in mortifications or sphacelations, though neither this nor any other degree of heat can restore motion in the sphacelated part, yet this degree is most likely to promote the circulation remaining in the confines of the mortified part; which is the only intention of fomentations and poultices in such cases, in order to a separation of the sphacelated stuff.

§ 2. This doctrine is confirmed by observations, that all animal fluids are thickened by any great degree of heat, or cold. Thus,

§ 3. The white of an egg becomes as hard in a night's time under the snow in frosty weather, as if it had been roasted by the fire, or boiled in water; though the yolk, being more oily, is not so much hardened in the same time; whereas it is known, that all parts within the shell are made more fluid by the heat of incubation.

§ 4. And hence it is, that the same kinds of inflammatory distempers appear in the summer heats, as in the greatest colds of winter: Whereas the temperate warmth of the spring and autumn is generally healthier, or at least freer from these kinds of inflammatory distempers.

*Obs.* II. § 1. Though the vein contains such a quantity of air, yet it is no way tumified or expanded by exhausting the receiver; which shews, that the real elasticity of the muscular fibres of the vein is superior to the expansive force of the inclosed air, in which its elasticity is imagined to consist.

§ 2. This elastic power of the vessels therefore would make a rupture of them impossible in an exhausted receiver of an Air-pump, or at the top of a very high mountain, such as *Teneriff*; did not the force of the circulation, at least in this last case, contribute to that rupture of the capillary vessels; which appears by spitting of blood in such eminences.

*Obs.* III. The manner of this experiment upon blood, which has never had any communication with the external air, obviates an objection against an Experiment of this kind, upon blood received into a porringer, or other vessel, from the arm by venæsection, which might be supposed to have imbibed or received air in its passage, and exposition to the external air, before the experiment.

*Obs.* IV. § 1. As the blood circulating in the vessels appears to have such a quantity of air intimately mixed with every molecule, globule, or particle of it, the whole compound according to the common doctrine of elasticity, ought to be looked upon as an elastic fluid: even if these globules themselves were not elastic, as I formerly endeavoured to prove them to be, in an essay on the structure and motion of the heart, read some years ago in this illustrious Society, and in a dissertation *de Struct. & Mot. Musc.* lately published.

§. 2. In the mean time it may be necessary here to obviate an objection against the elasticity of all fluids, which arises from the incompressibility, and therefore, as is alleged, the non-elasticity of water, the basis of all the rest; even though it be known to contain a great quantity of air. For this purpose the *Florentine* Experiment of filling a spherical vessel of gold full of water, closely shut up in it, and exposed to the strokes of an hammer on an anvil, or to any other strong compression, is offered in proof. Because in that Experiment it appears, that some part of the water will make its way through the pores of the gold; which plainly shews, that it cannot be compressed into less room than it had in the spherical vessel, which is more capacious than the cavity of an oblate spheroid, to which the strokes of the hammer, or other compression, may have reduced it.

§. 3. The solving of this difficulty will give an handle for clearing up some mistakes, relating to the imagined non-elasticity of fluids, for which reason it may not be improper in this place to give some account of the nature of elasticity.

## Of E L A S T I C I T Y.

Elasticity being one of the principles of muscular motion, it is necessary to shew where it resides, and how it acts. In order to this, I shall offer the following propositions, some of which are so evident as to want no proof, and to the rest the proper proofs shall be subjoined.

*Prop. I.* The *minima* of all bodies are perfectly hard; that is, their parts are neither separable, nor

capable of changing their relative situation, by any power in nature. This is supported by the incomparable Sir *Isaac Newton*, in his treatise of optics, by irrefutable arguments, which I need not here repeat.

*Prop. II.* Therefore, as the *minima* of bodies cannot be singly elastic, elasticity must be a property of compound bodies only, whose component parts are capable of changing their relative situations, and can be drawn to various relative distances with regard to one another.

*Prop. III. §. 1.* This property appears to be greater or less in all compound bodies, whether solid or fluid; but the question is chiefly about the elasticity of fluids, which has been positively denied in water (the basis of all the animal and vegetable fluids) upon the score of its incompressibility, observed in the *Florentine* Experiment mentioned above. But notwithstanding that Experiment, I believe it may be made to appear, that water, oil, and mercury, are not only elastic themselves, but also the causes of elasticity in all compound solid bodies.

§. 2. In order to this, we are to consider: That the natural state of all elastic bodies, whether solid or fluid, is contraction of all the parts of the compound towards one another, and to the common centre of the mass. This appears in a bow, and after the same manner in a drop of water, dew, or mercury, whose particles are all equally attracted towards the common centre of the mass, even in *vacuo*, according to the VIth Experiment, and therefore towards one another, so as to form the exactest sphere about that centre, where they remain in *equilibrio*, and immoveable

moveable by any power or force of their own; and if disturbed by any external force (short of what will dissipate them into lesser spheres) so as to be reduced to oblate or oblong spheroids, or to any other figure different from that of a sphere, they will immediately upon removal of that force resume their former spherical figure, situation of parts, and *æquilibrium*, about their common centre, as before: and in their progress towards restitution, they will either repel, or constantly endeavour to repel, the incumbent or impelling force.

*Corollary.* Thus fluids appear to be elastic, as they are capable of extension or expansion by any external force applied; and of restitution to their pristine figure by their own natural force, by which they repel, or endeavour to repel, every thing that stands in the way of their restitution. Which is the whole characteristic of elastic bodies.

*Scholium.* Repulse therefore (in this case at least) appears to be no principle of action, but the effect of that principle, which is rightly called contraction or centripetal force; which I have endeavoured to shew elsewhere. [See *Diff. de Str. & Motu Musc. Introd.*]

§. 3. As to the *Florentine* Experiment, which is offered in contradiction to this quality in water, we are to consider, that cold water is before the Experiment, in the state of its ultimate condensation or contraction which it can have at that time or season in which the Experiment is made, with an immediate contact, or the nearest possible vicinity of all parts of the compound, whose *minima* are perfectly hard, as has been already proved; and also perfectly round,  
which



which its fluidity shews to be very probable. Such a body, I say, in its natural state of contraction cannot be brought into a nearer contact of parts, nor into a lesser compass than that of a sphere, which is the most capacious of all figures, under the same surface; and therefore cold water, or any other fluid, shut up in a vessel of that figure, would either constantly resist the compression, or escape it even through the pores of gold: which no way invalidates the arguments offered above in proof of its elasticity. For though an elastic body extended, distended, expanded, or rarified, may be contracted or condensed, either by its own natural power, or by an external force superior to that by which it was extended or rarified; yet it does not from thence follow, that after its full natural condensation or contraction, it can be still further condensed or contracted, by any force whatsoever: which does not at all imply a want of elasticity, such as has been above described.

§. 4. It may be further added, that if it was possible to condense any pure elastic solid body, beyond the ultimate degree of its natural contraction and condensation, when all extraneous or heterogeneous bodies are removed; then we should be able to alter the specific gravity of bodies, and so far the transmutation of metals would be no longer a mystery. But there is no known power in art or nature, by which pure gold, silver, mercury, or any other pure homogeneous metal, can be made denser, or its specific gravity increased. It is true, that in impure metals, by removing the impure or less weighty particles out of the way of the mutual contact of their purer

purser parts, the remaining pure parts become heavier and denser, than an equal bulk of the original mass : but this is only a purification, not a condensation of the primary essential component particles ; which, was it possible, would alter the specific gravity, and therefore the species of the metal, and so introduce a new species of pure metal. Which, I believe, is beyond the power of art, or any known power of nature.

§. 5. The second thing to be considered in elastic bodies, whether solid or fluid, is a capacity of being extended, distended, expanded, or rarified ; the effect of which is also to repel any incumbent or impinging force ; which is sometimes done with very great violence and impetuosity in a direction exactly contrary to the centripetal force above described, and therefore has been called, though, I think, erroneously, the centrifugal power of elastic bodies, observed in various experiments on the air, whence it is denominated the most elastic of all bodies. Of which more hereafter.

§. 6. But I must observe, that the same expansive power, and even a greater force of repulsion, appears in water, rarified in the *Æolipile* and *Fire-Engine* ; though it be not allowed to be elastic.

§. 7. But the truth is, that this expansion, and repulse which attends it, do not seem to be natural powers either of air or water ; but effects produced in them by the force of fire, the rays of the sun, or heat, in a direction contrary to the elastic centripetal natural powers of these two fluids: so that rarification or expansion in them is not a natural action of their

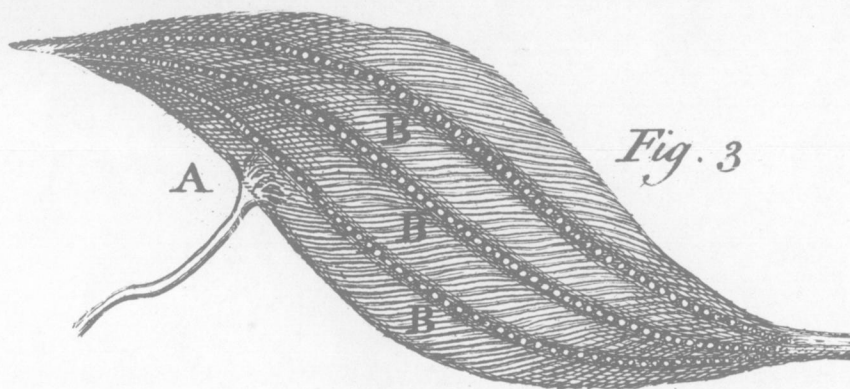
their own, but a forced effect; and therefore the repulse arising from it must also be the same.

§. 8. And this is equally observable in all elastic solid bodies. For example, a bow that lies unbent, cannot be bent by any force of its own elasticity, but by the impulse of some adventitious external power, which really extends it, or draws it to a greater length in the bending: therefore the bow is not then said to act, but to be acted upon, in order to its subsequent action of restitution; and the man's hands and arms in acting upon it repel whatever stands in the way of their action. But this action and repulse is never ascribed to the bow, whose action is restitution, or a centripetal motion only, by which the arrow is projected by repulse, or reaction of the bow upon it in its restitution or contraction.

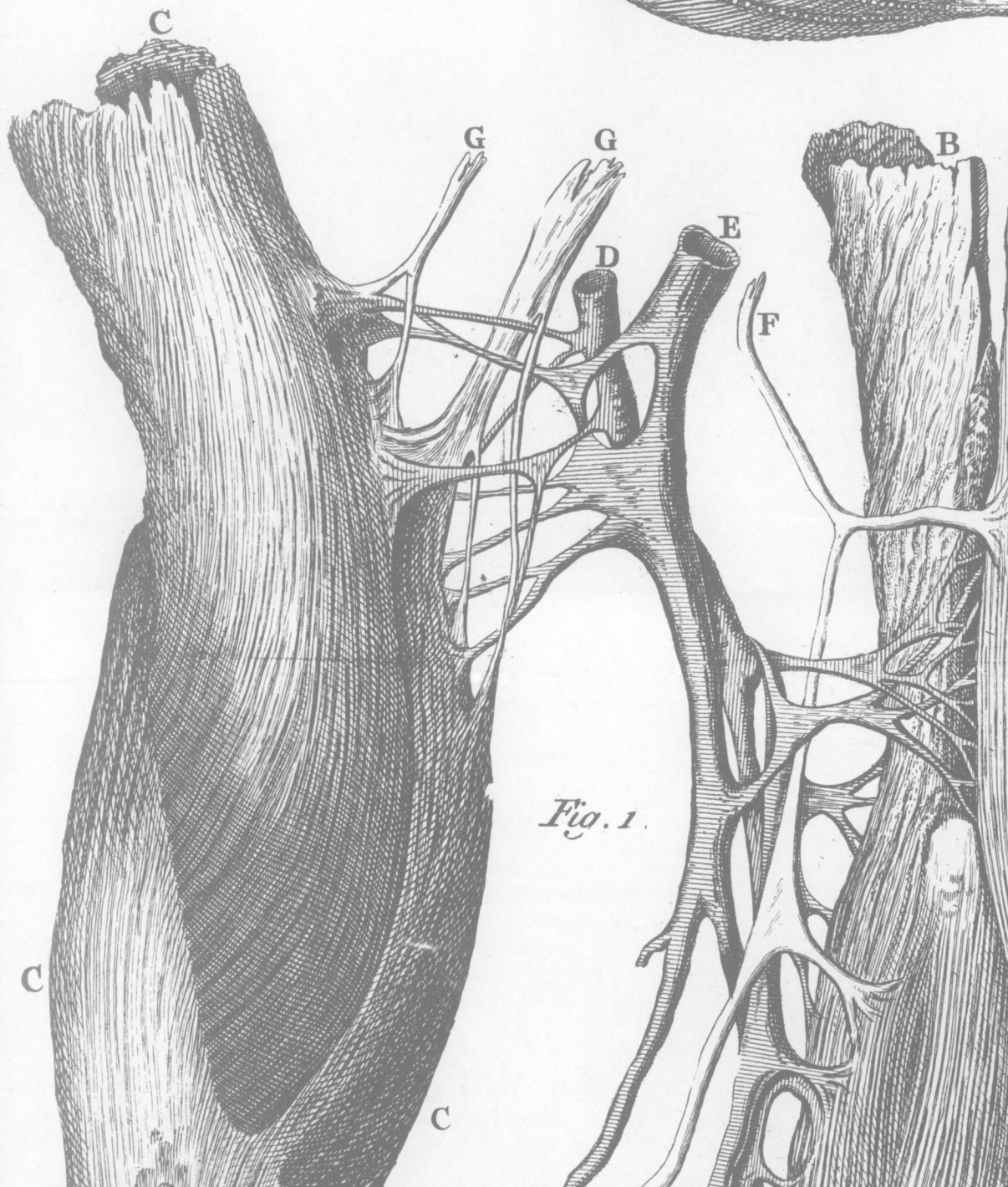
§. 9. It is in the same manner, that the rays of the sun, fire, or heat, expand and rarify condensed air, or water, and repel whatever stands in the way of their action, and that *undequaque* in the manner of all other fluids; in which action the velocity of the particles of fire, communicated to the particles of a weightier fluid than itself, increases the *momentum* of the expansion and repulse, in proportion to the different weights of the fluid acted upon: therefore the force of this expansion and repulse is found to be far greater in rarified water or steam, than in rarified air; as is evident in the *Æolipile* and Fire-Engine.

§. 10. Thus it appears, that this expansion and repulse is not owing to the natural elasticity of the air, but to a foreign power, to wit, that of fire or heat, acting upon it.

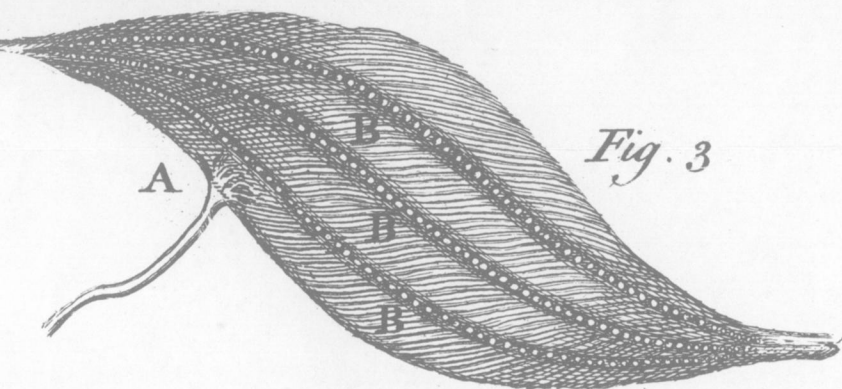
§. 11. And



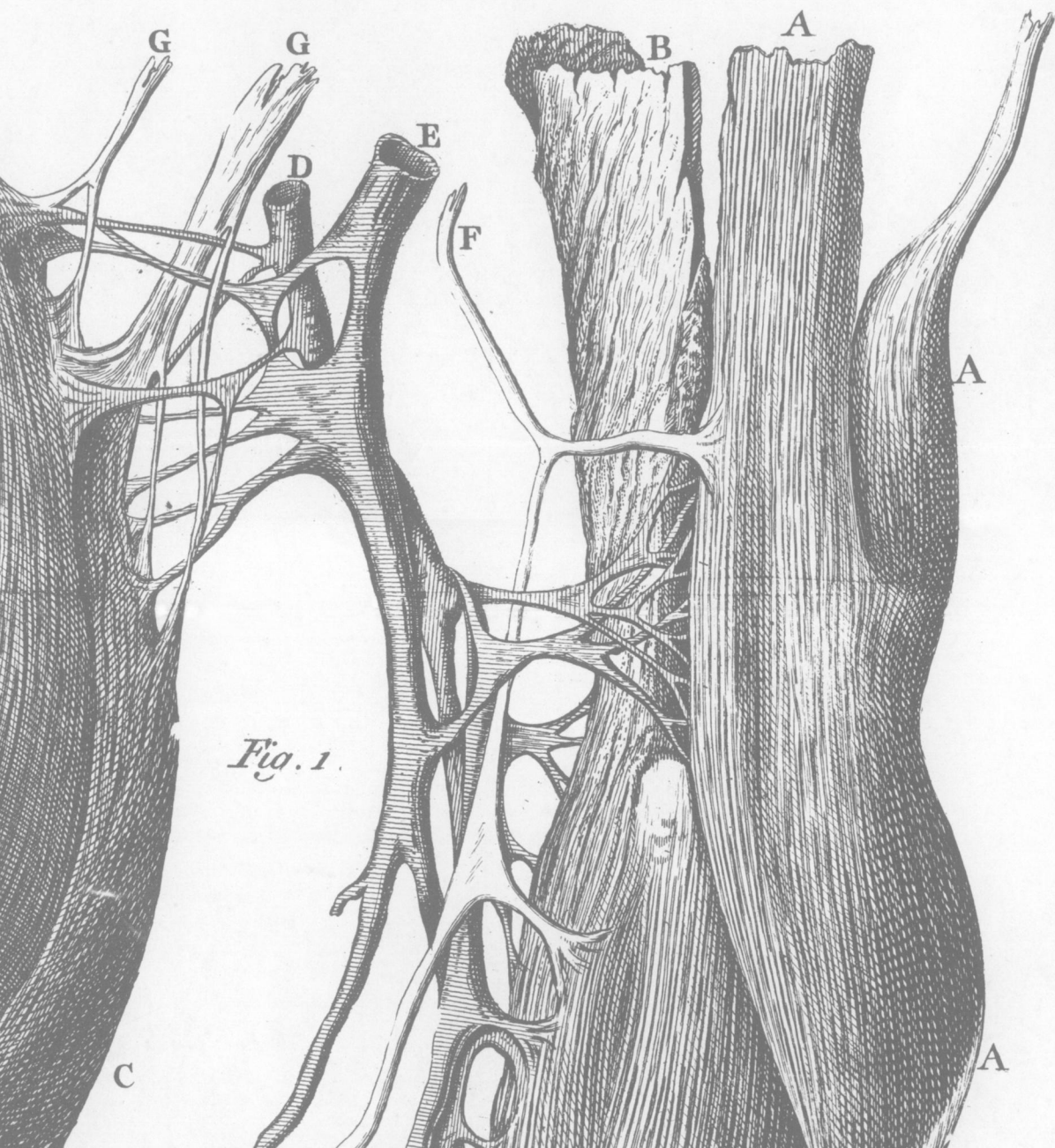
*Fig. 3*



*Fig. 1*

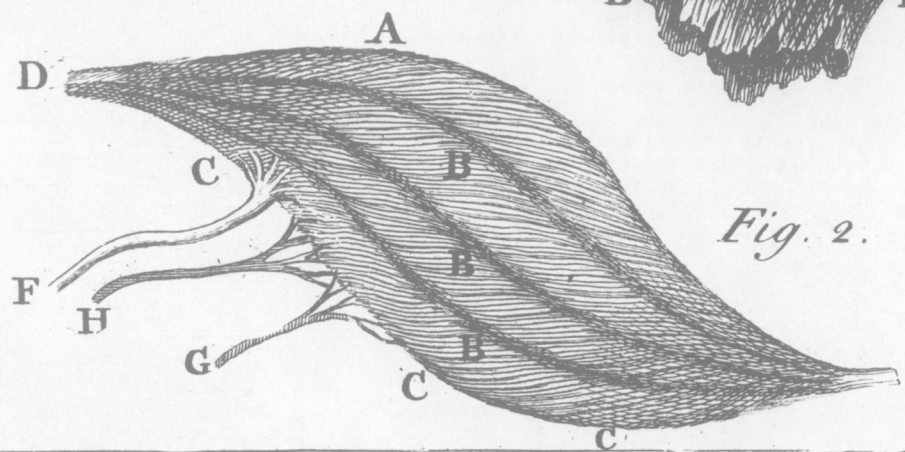
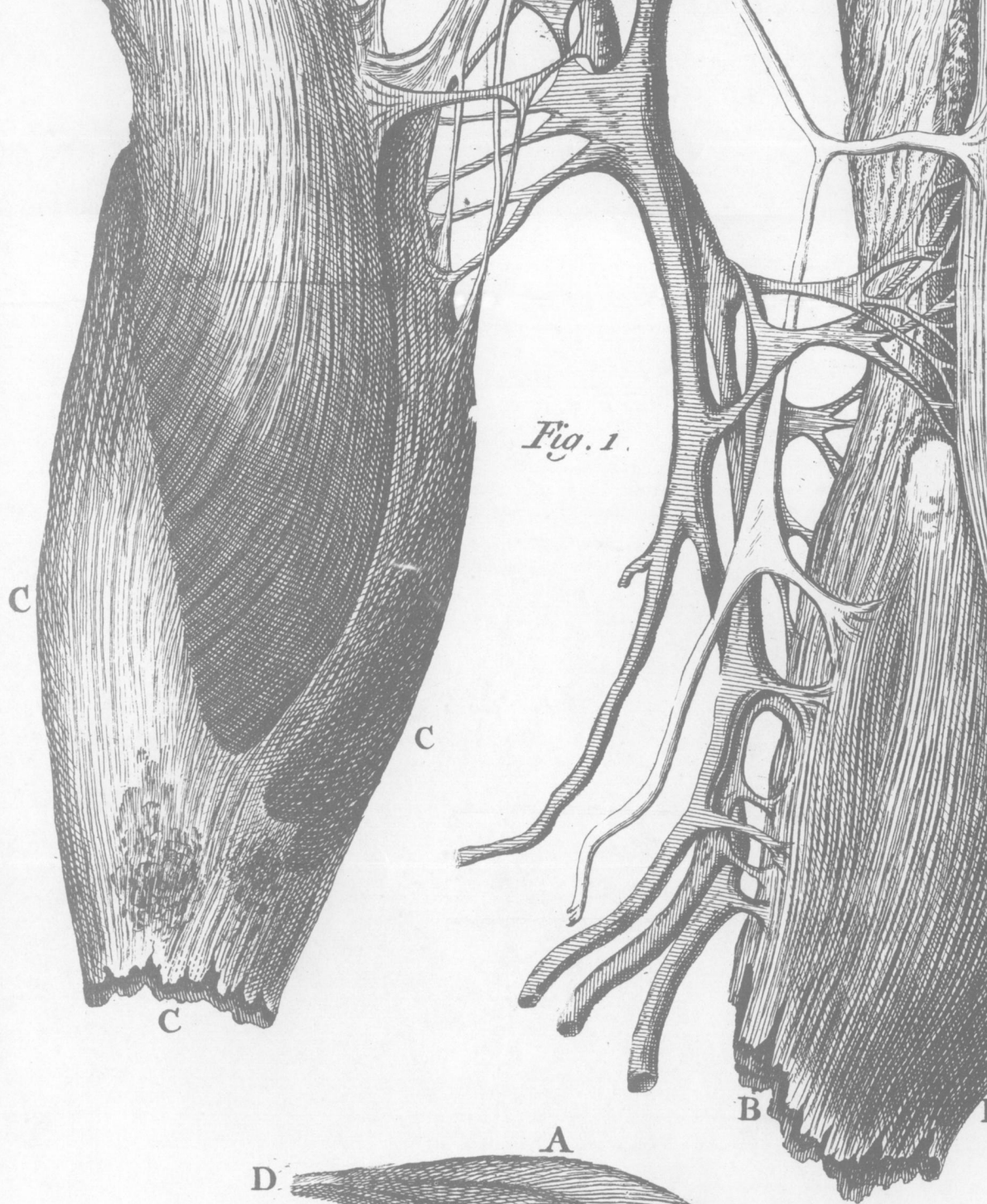


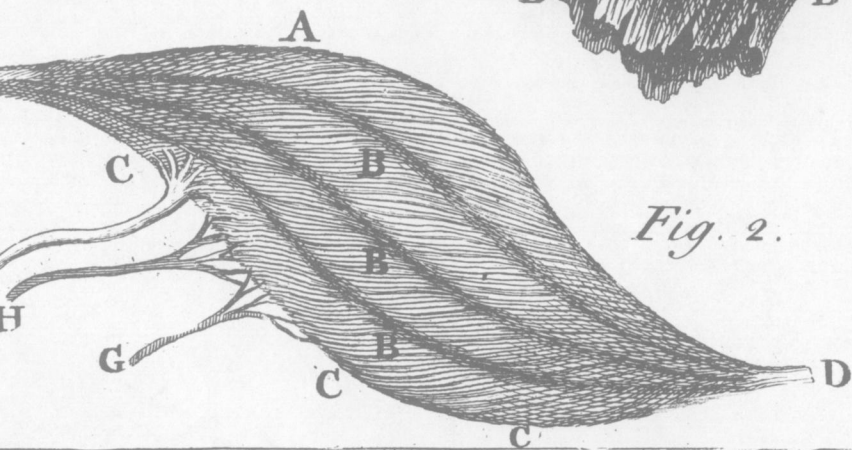
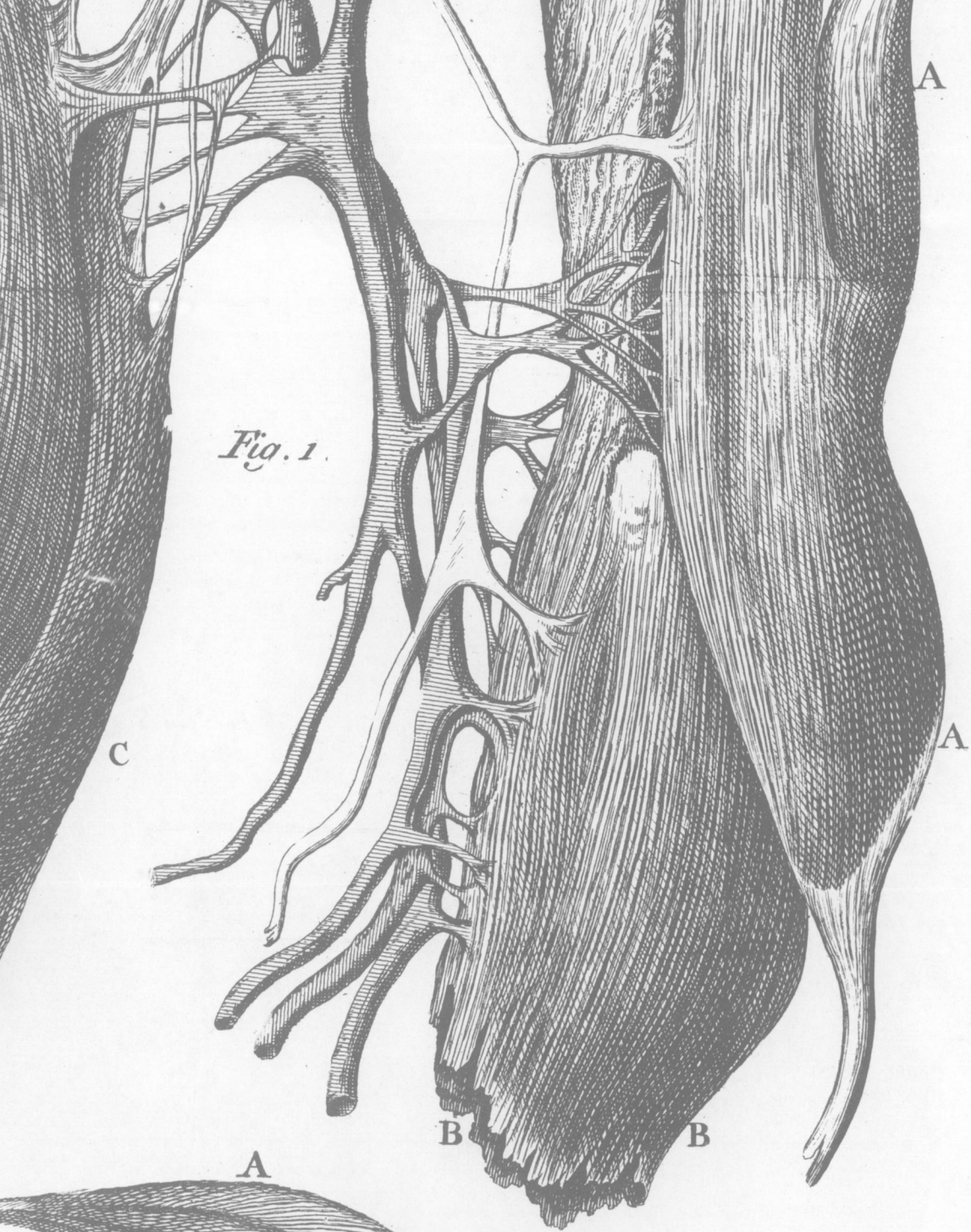
*Fig. 3*



*Fig. 1.*







§. II. And this is confirmed by observing, that air long shut up from the rays of the sun, and from all communication with the external air, which conveys them: I say such imprison'd air at last totally loses this expansive power, so as to become unfit for respiration, and will extinguish a flame, or kill an animal, as quickly as if they were stifled in *vacuo*. Which indeed is the case. Whence it is commonly, but I think, wrongly said, that such air has lost its elasticity. As if we should say, that a bow has lost its elasticity, because we see it lie still, contracted, or unbent, and no hand employed to extend, that is, to bend it; without considering, that no elastic body can act until it be first acted upon.

What may be further said on the head of elasticity, shall be the subject of the next Lecture.

## L E C T U R E II.

**I**N the last Lecture I endeavoured to shew, 1<sup>st</sup>, That the *minima* of all bodies are perfectly hard.

2<sup>dly</sup>, That elasticity therefore is a property of compound bodies only.

3<sup>dly</sup>, That this elasticity consists in a capacity of a change of figure, or change of the relative distances and disposition of the parts in the compound, without a solution of contiguity or continuity of its parts; and a centripetal power of restitution to the same figure again.

4<sup>thly</sup>, That the natural state of all elastic bodies, whether solid or fluid, is contraction only.



5thly, That their forced or preternatural state is extension, expansion, dilatation, or rarification by some foreign adventitious force.

6thly, That this natural state of contraction in homogeneous fluids arises from a centripetal force, by which all parts of the mass tend to one common centre; and therefore to one another in *æquilibrio* about that centre, so as to form the exactest sphere, as a figure capable of a greater quantity of matter, than any other figure of the same surface.

7thly, That therefore in such a state of ultimate contraction, they are not capable of any further contraction, condensation, or compression, so long as they continue in a state of fluidity; which does not at all impugn their elasticity, or invalidate the arguments produced in proof of it.

8thly, That repulse is not a principle of action in elastic bodies, but the effect of that natural principle which is justly called centripetal power, or a *nîsus* towards æquilibration about some common centre; by which they repel, or endeavour to repel, whatever stands in the way of their restitution to that *æquilibrium*.

9thly, That as expansion, distention, and rarification are not the natural actions of elastic bodies, but the forced effects of some adventitious external or foreign cause; or of an addition of more matter of the same, or some other kind, acting upon them; therefore the subsequent repulse produced is also the effect of that same external cause, or of such addition, and not of the elastic body itself, whose sole action is restitution towards its own centre, in a direction contrary to the power of that external agent.

These

These conclusions I endeavoured to illustrate by instances from a drop of water, dew, mercury, stagnating and imprisoned air, a bow, &c. I shall now proceed to consider these a little further, together with some other sensible properties of fluids; that by comparing them we may be able to draw such general conclusions for our purpose, as shall appear to flow necessarily from them, in confirmation of what has been already said, and for a further illustration of this subject.

*Section 1.* There appears to be only four kinds of fluids, visible and obvious to the touch, namely water or watery fluids, oil, mercury, and fire; the last of which, though the most universal and most powerful of all, we are certainly the least acquainted with.

§. 2. The air as it is not a visible fluid, and is known to be an heterogeneous mixture of almost all sorts of fluids; until we are at some certainty about the properties of the other more simple and more sensible fluids, of which it is composed, it is not likely that we can come to any solid conclusions concerning it: therefore this may more usefully be the subject of some following Lectures.

§. 3. The first property that I have already touched upon in water, is, that the minuteſt, visible, diſtinct drops of it, and even pretty large ones, as well *in vacuo* as in the open air, (according to the VIth Experiment made) form themſelves into exact ſpheres; in each of which the centre of magnitude appears to be the centre of gravity, attraction, and æquilibration, as alſo of vibration or elſticity. And in ſuch ſmall drops it continues to be ſo, as long as the attraction of each particle of the fluid within that ſphere is greater to-

wards its own centre, than towards the centre of the Earth : that is, until the drop be so increased, that the gravity of the extreme particles of its surface exceeds their attraction towards the centre of the drop, as placed at too great a distance from it, to be sensibly or sufficiently affected by it. In which case, though they do not lose their mutual attraction towards each other, and therefore retain a proportional attraction towards their common centre ; yet they are forced to yield to the superior power of gravity, by which they form themselves into a small part or section of a larger sphere, about that more powerful centre of the earth. This is most remarkable in the ocean, where the water affects and obtains the same spherical figure about the centre of the earth, as the least drops do about their own peculiar centres.

§. 4. And this attraction of its particles in *æquilibrio* towards the common centre of each small drop, is distinct from, and independent of, the action of the specific gravity of the whole drop towards the centre of the earth, the one being no ways hindered or promoted by the action of the other ; which appears by the constant sphericity of their figure, whether they ascend in steam or vapour, descend in rain or dew, are suspended in a fog, or lie or hang on the leaves of grass ; either in the open air, or *in vacuo*.

*Corollary.* Therefore the same hydrostatical laws, which take place in the ocean, or any other considerable collection of water, whose surface forms itself to a convexity about the centre of the earth, must equally take place in every distinct drop of water, whose surface forms itself to a convexity about its own peculiar

liar centre. And such of these laws, as may serve for our present purpose, shall be taken notice of in the sequel.

§. 5. The second property that I would take notice of in water, is, that it is very plentifully attracted into the pores, vessels, interstices, and innermost recesses of all solid animal, vegetable, and terrestraneous substances, where it diffuses itself equally, and uniformly, *quaquaversum*; and constitutes in some one half, but in the greatest number more than half of their bulk or weight: to say nothing of tin, antimony, sulphur, and some other mineral substances, where it is also found; for which the chymists may be consulted, and particularly the most accurate and learned Dr. *Boerhaave*, in his incomparable Treatise of the Elements of Chymistry.

§. 6. I shall only offer one remarkable instance of this in the IVth Experiment made on a species of *Thlaspi*, commonly called the *Rose of Jericho*, *Rosa Hierichontea*, which in its vegetating state spreads its branches all round, almost horizontally, from the top of the root, near the ground, as from a centre: see tab. 1. fig. 2. When it has perfected its seeds, it appears of a hard, woody contexture; and as it grows dry, the branches contract and curl themselves up towards their centre, so as to form a spherical figure: see tab. 1. fig. 3. in which state this plant weighed seven drachms and a few grains; but after having been steeped two hours in luke-warm water, it expanded its branches as you see; and it weighs now 13 drachms, which is but one drachm less than the double of its former weight in its dry state: see tab. 1. fig. 2. How much more  
water

water then, or watry juice, muſt it have contained in its green and growing ſtate?

§ 7. Some green plants indeed contain more juice than others, but almoſt in all of them, when pounded and ſqueezed, the juice is found greatly to exceed the huſky or dry part. This exceſs of the fluids in vegetables is exceedingly remarkable in all the ſucculent kinds, and is little or nothing leſs in living animals, and recent animal ſubſtances; Experiments having ſhewn, that after waſte or expulſion of all the fluids by deſiccation or diſtillation, the remaining ſolid parts appear to bear a very ſmall proportion to the fluids.

*Corollary.* Therefore the few rigid and leſs moveable ſolids in all animal and vegetable ſubſtances muſt in action yield to, and be governed by, the hydroſtatical and hydraulic laws of the fluids, ſo plentifully contained in them; as that which has the greateſt *momentum*, ariſing from its weight and celerity, will in all motions overpower what has leſs.

§ 8. This is in a good meaſure remarkable in the *Heath Roſe* juſt now ſhewn, where the force of the fluids, tho' urged on by no other power than the attraction of its ſmall pores and capillary tubes, was ſufficient to expand and extend the branches, and veſſels of which they are compoſed, from being ſegments of leſſer to form ſegments of much larger circumferences of circles, or other curves; which no external force can do, without breaking them to pieces.

§ 9. This Experiment ſerves alſo to prove and illuſtrate, what I have advanced elſewhere, concerning the  
power

power of the blood propelled alternately by the force of the heart and arteries into the branches of the blood-vessels, investing the cavities of the intestines and vesicles of the lungs, for forwarding the diastole or expansion of these cavities in the peristaltic motion and inspiration; to wit, by a force in the direction of the tangents of the arches of these vessels and cavities, which is a direction perpendicular to their centripetal elastic contractions; as they appear in these draughts of the intestines and vesicles of the lungs before you. See *Diss. de Struct. & Motu Musc.* tab. II. fig. 1, 2, 3. and tab. V. fig. 5.

§ 10. The third property observable in water is, that it is the cement of union of the solid parts in all animal, vegetable, and terrestrious substances. A paradox, which nothing but experience could render probable; to wit, that a fluctuating body, whose parts may be so easily disturbed, displaced, or separated, should give firmness, hardness, rigidity, and stability, and prove a *copula* of union to other particles of a mass, which could never unite among themselves without it. Yet this is obvious in making of bricks, mortar, and figures in plaister of *Paris*, and also in the distillation and calcination of all vegetable and animal substances; where, after the total expulsion of all the fluids, nothing remains but incoherent loose dust or ashes, incapable of uniting again without a new recruit of moisture.

§ 11. The fourth property of water is, its being the universal dissolvent of all these very substances, of which in the preceding section it is observed to be the cement. Which also at first sight seems another paradox; because to unite, and divide, are evidently two  
contrary

contrary actions. I shall therefore in the sequel endeavour to shew, how consistently they flow from one and the same principle, acting by the same instrument.

§ 12. The fifth very remarkable property of water and other fluids is, that they are capable not only of an alteration of figure, or different position of parts, without the loss of contiguity, as has been said already; but are also liable to have their parts separated to small distances by expansion or rarification, or to greater distances by evaporation or dissipation; which is evident in water, spirit of wine, oil, mercury, and all other kinds of fluids exposed to the fire, or heat, of any sort. In which circumstances they very forcibly, and in some cases almost irresistibly, repel every moveable thing, that stands in the way of their expansion or evaporation, even to the pitch of explosion at the places of least resistance: as appears in the *Æolipile* and *Fire-engine*.

§ 13. The principles from whence this expansive power and repulse arise have been mentioned already. I shall now apply what has been said in this, and the former lecture, towards a further explanation of the universal elasticity both of fluids and solids.

§ 14. 1<sup>st</sup>. It has been generally supposed, that when the solid particles of an elastic body are drawn out of contact to some very small distance by extension, they have a power of restoring themselves to their former contacts again by their mutual attraction; in which the elasticity of compound solid bodies has been said to consist. But if we may depend upon what is visible, we shall never see the dry solid fibres or particles of any solid body, once divided or drawn out of contact, coalesce or unite again, or recover the close contacts

contacts they had before ; without some fluid medium superadded. And therefore if the least fibre of a bow, or other elastic solid dead body, be once crack'd or broken, the rupture will always continue the same; and notwithstanding the elasticity remaining in the other parts of the bow, by which the broken or divided parts are brought again within the same bounds of vicinity, through which this attractive power is said to extend, nevertheless they do not again coalesce or cohere.

§ 15. It is further observable, that if a drop of water, oil, or mercury be divided into many lesser drops, and placed at the least imaginable distance from mutual contact, they always remain distinct and disunited; but upon contact they are absorbed into each other with a visible rapidity, and become one as before.

*Corollary.* Therefore there is some reason to conclude, That the power of attraction does not reach much, if at all, beyond contact, either mediate or intermediate; and that it takes effect in solids only by the mediation of fluids. Again, it is apparent, that within the limits of contact it is very sensibly strong in fluids.

§ 16. This quality in fluids with their capacity of change of figure, or disposition of parts in the mass, to every imaginable shape, without a solution of continuity or contiguity; and with a power of returning to their pristine figure, or disposition of parts, within their former surface again, when left to themselves; these qualities, I say, are sufficient to establish elasticity as a natural and essential property of fluids, not discoverable in pure or simple solids, without their mediation or assistance.



§. 17. For by what has been said of solid bodies, when destitute of all humidity, or deprived of all their fluids, it appears evidently, that none of the aforesaid qualities can belong to them; and therefore as solids they can have no elasticity of their own, nor any degree of it, but what is borrowed from the fluids they contain. An instance of this is in the artery before you, whose elasticity while recent and moist was shewn before in the first Experiment; but being now dried is neither capable of extension or distension, but remains rigid and contracted, until it be steeped again some hours in water, by which it will recover its former elasticity. In which state it shall be shewn again at the next meeting.

§. 18. If elasticity therefore resides solely in fluids, and only by their intervention in solids, we are now to consider how, and with what force or *momentum*, it acts there.

§. 19. Elasticity then, at least in animal and vegetable substances, being an essential property of their fluids, and of them only, the laws of elasticity and hydrostatics must be the same, these last arising from the nature of fluids, as well as the first; and there can be no incongruity, contradiction, or inconsistency in the same nature or essence: therefore the known hydrostatical laws will give us the laws of elasticity, which must take place equally *in minimis ut in maximis*, in a drop of water as in the ocean.

§. 20. It is a general law in hydrostatics, that the pressure of fluids is in proportion to their altitude or height, and the surface against which they press; and not in proportion to their breadth.

§. 21. Another

§. 21. Another general law is, that in the same altitude they press equally in all directions, or *quaquaversum*.

§. 22. From these two general laws arises another special one, which is commonly called an hydrostatical paradox: to wit, that a cylinder of water of any given height, communicating with a vessel set under it of any given diameter larger than its own, and full of the same fluid, presses upon the bottom, sides, and cover of that vessel, with a force equal to the weight of a cylinder of water of the height of that cylinder, and of the diameter of the under-set vessel; and, if the vessel be distensible, it will distend it, or enlarge its cavity by all that force; which may be indefinitely greater than the weight of the whole water, contained both in the vessel and in the cylinder: which mechanical disposition of the fluid produces a great multiplication of power, in proportion to the height of the cylinder, and breadth or diameter of the communicating under-set vessel.

§. 23. Let us then only for the present suppose, what seems highly probable, that the pores and interstices, at least, of solid animal and vegetable bodies are round, as their vessels are known to be cylindrical; and that the water, every drop of which tends naturally to sphericity, being attracted into them, is lodged there in small *spheres* or *cylinders*; this being the contracted shape, which they naturally take, as comprehending most matter within the least surface. Now if the solid body containing them in its pores or vessels be drawn, bent, or extended to a larger surface, containing the same quantity of matter, the fluids in it must yield to that force; and therefore each drop must take some figure different from that of a sphere, or become a

cylinder of a lesser diameter ; that is, its surface must be extended or expanded, so as to become an oblate or oblong spheroid ; or it must take some other figure different from that of a sphere, and adapted to the figure, which the pores and interstices of the solids or the vessels themselves are reduced to by the extension. But so soon as the bending or extending force ceases, and the whole solid body is left to itself, the particles of each drop will endeavour to recover their *equilibrium* about their peculiar centres, whereby they recover their sphericity, or contraction again into the least possible spherical or cylindrical space ; by which the restitution in every part, and therefore of the whole, is performed, the contiguous solids yielding to, and conspiring with, the *momentum* of the fluids in this action.

§. 24. But for the sake of illustration only, let us again suppose a thing less probable : to wit, that by the extension of the containing solid a part of each distinct drop should be raised beyond the surface, in the shape of a small cylinder, by which the diameter of the drop would be lessened ; this small cylinder then would press towards the centre, and all sides of the drop, with the same force mentioned in *Section 22* ; and in the restitution the diameter of the drop would increase proportionally, as the length of the cylinder in its descent or accession towards the centre of the drop decreased : therefore it would descend or accede to that centre by a motion uniformly accelerated ; as in gravity. And in this view we have gravity and elasticity arising from one and the same principle.

§. 25. But the same argument will hold, and the same conclusion will follow, upon the other more probable  
sup-

supposition: to wit, if by the extension of the solid containing body, mentioned before, each distinct drop be supposed to be drawn from its sphericity into an oblong spheroid, or pressed to the form of an oblate one; for the restitution in both cases will produce the same effect from the same hydrostatical principles, since what-ever part of the fluid is extended beyond the bounds of its former spherical surface, will thereby have an increased pressure towards the centre, such as the cylinder has been said to have, or in such a *ratio*: because the rays terminating in the uncompressed parts of the surface of the oblong or oblate spheroids of fluids, are lengthened by the new accession of particles from the compressed sides, by which the pressure towards the centre in such lengthened lines will be increased, in proportion to their lengths; and the shorter diameters of each *spheroid* will be proportionally lengthened, as these lines in acceding to the centre are shortened: that is, the particles, which lie in the direction of the longer diameters of the *spheroid*, in the restitution will accede towards the centre, with a motion uniformly accelerated, as in gravity. The same will be true of a cylinder, whose diameter is shortened, and its axis lengthened, by the compression or extension.

*Corollary.* Therefore the laws of gravity, hydrostatics, and elasticity, are probably the same, and arise from the same principle of central attraction, only diversified in almost an infinity of *phenomena* both natural and artificial, by the diversity of centres, circumstances, and different qualities of the bodies acted upon.

§. 26. And this conclusion seems to be corroborated by the VIth Experiment made at last meeting on water, oil, and mercury, in which it was apparent, that the centripetal force of these distinct fluids differed one from another in the proportion of their specific gravities. The drop of mercury, as the heaviest, formed the most perfect sphere about its own centre, and the least; the drop of water, though spherical, touched the plain in more points; and the oil, though its upper surface was spherical, lay much flatter on the plain, forming as it were a section of a small sphere. Therefore the centripetal force in each was proportional to its specific gravity; which seems to shew, that it flows from the same principle, acting on the same subject always with the same degree of force, only on each species to a different centre with a different degree of force or *momentum*; whereas, if the centripetal force in each of these drops did arise from some other principle than that of gravity, it might be stronger in the lightest than in the heavier fluids. For as gravity is a power, which acts equally on all bodies in the *ratio* of their contents, if this centripetal power, being equal in all bodies, was in some other *ratio* or proportion, than that of their contents; then it would act most strongly and sensibly on the lightest fluid, whose gravity and contents could least resist its force: and therefore the drop of oil would form a perfecter sphere, than the mercury; the reverse of which appeared in the Experiment.

§. 27. Another thing that I would suggest from the Experiment is, that if a drop of each of these three fluids could be taken equal one to another in weight, the cubes of the diameters of the spheres formed by them  
would

would be one to another reciprocally as their specific gravities ; in the same manner as the spaces they take up in the same cylindrical vessel are reciprocally as their specific gravities. Which confirms the former conclusion, that this centripetal power in fluids, and therefore their elasticity arising from it, does not differ from gravity, and is governed by the same laws ; producing a motion uniformly accelerated, as in the descent of heavy bodies.

*Corollary.* Therefore the laws of gravity, elasticity, and hydrostatics, are the same ; and arise from the same principle.

Having thus endeavoured to prove, that water and watery fluids are not only elastic themselves, but also the immediate cause of the elasticity of all animal, vegetable and terrestrial solid substances, of whose composition they make a very considerable part ; it is now incumbent to shew, how its other seemingly contrary properties formerly mentioned, are reconcilable one with another, and also with this essential property of elasticity : particularly how water and watery fluids can prove the cement, and likewise the dissolvents of animal and vegetable, and also of many terrene bodies : or can become the causes of so very different and even contrary effects, as to unite and divide the parts of the same subject ; and this by that single property of central attraction.

In order to the easier illustration of this, I would offer the following propositions, which are either evident of themselves, and universally acknowledged, or founded upon Experiments, or proved in this and the preceding Lecture.

*Prop.*

*Prop. I.* There is a natural centripetal power in water, and indeed in all other fluids, by which every distinct drop, or certain small quantity, left to itself, gains and retains an exact sphericity. This I hope has sufficiently appeared by the observations and experiments already made.

*Prop. II.* The degrees of the intensity of powers propagated in rays from a centre, or impelled in a contrary direction towards the centre, are found to be reciprocally, as the squares of the distances from the centres of the respective spheres of their activity.

*Cor.* Therefore as water appears to have such a centripetal power, it follows, that the extreme or superficial particles of the smallest drop of water press towards one another, and towards their common centre, more strongly, than the superficial particles of a larger drop, or of the same drop, augmented to a larger size by the accession of more water.

*Prop. III.* There is an universal impenetrability in matter, so that one quantity cannot take place, without dislodging another of equal bulk or surface.

*Prop. IV.* And in this action, that which has the greater *momentum* will overcome or displace that which has less.

*Prop. V.* The quantity and celerity or *momentum* of a fluid in motion may be such, as to overcome the resistance of solids at rest.

*Prop. VI.* Water and other fluids in contact with solids, acquire a degree of motion by attraction into their pores, capillary tubes, and interstices, even to their innermost recesses, so as to swell, extend, or expand them. Instances of this were shewn in the *Rose of Jericho*, and in an human artery.

*Prop.*

*Prop. VII.* And the degree of attraction of the same species of fluids into the same kind of solid being always equally the same, the celerity of the motion arising from it will also be always the same. Therefore the increase of the *momentum* of the fluid in this action must arise from the increase of the quantity of the fluid so absorbed; which may therefore be accumulated not only to the pitch of extension, expansion, and softness, but even to a perfect solution. Which all observations confirm.

§. 28. These propositions being admitted, it will appear, that the cohesion of solids in their various degrees of hardness, solidity, rigidity, or less sensible elasticity, manifest elasticity, and softness; and also their perfect solution, even to the state of fluidity, do all arise purely from the different quantity of water, or other fluids, lodged in their pores, or between their solid particles.

§. 29. Thus the incoherent dust of dry clay, and fine gravel, by a considerable quantity of water added in making of bricks, become a soft ductile kind of paste, *Prop. VII.* but by losing a great deal of this moisture in drying, or baking, becomes a hard solid mass. In which nevertheless a considerable quantity of water still remains in distinct drops, lessened in their size by the evaporation, and therefore having their remaining particles more strongly attracted to their respective centres, and one to another; and consequently producing a stronger adhesion of the contiguous solid particles to the pitch of hardness, rigidity, and a less sensible degree of elasticity. As in *Cor. Prop. II.*



## Lect. II.

[ xxxiv ]

§. 30. This also appears for the same reason in dried lime-mortar, and plaitter of *Paris*; and must be the same in the natural concretions of common stones, marble, &c. in all which the moisture has been by degrees evaporated to their specific pitch of hardness. And hence it is that all quarry stones, by being exposed to the open air for some time, become gradually harder, than when they were cut out of the quarry.

§. 31. But when the remaining moisture is farther or totally expelled by the force of fire, they return to their original incoherent dust, dry powder, or lime.

§. 32. So that the cohesion of parts in solids of this kind to the pitch of hardness, rigidity, or less sensible elasticity, arises from the smallness of the spherules or drops of water interspersed in their pores; which makes them less capable of extension, dilatation, or sensible elasticity. See *Cor. Prop. II.*

§. 33. The same appears in dry wood, and other vegetable solid substances; and in the dry bones, horns, and nails of animals; whose hardness or rigidity is owing to their desiccation, or to the evaporation of a certain proportion of their moisture; the remaining small portion making the solids in them cohere more strongly, for the reasons mentioned in the same *Prop. II.*

§. 34. And when this remainder is also expelled by the force of fire, having lost the *copula* of union, they fall to dust and ashes.

§. 35. Or if the proportion of water be greatly increased by infusion, maceration, or decoction, they  
are

are brought to a softness or solution by the *momentum* of the increased fluid. As in *Prop.* VII.

§. 36. This is farther evident in the making glue of the dry skins of beasts, and of fishes; and paste of starch; whose agglutinating quality is owing solely to the proportions of water absorbed, or intermixed by infusion, maceration, or decoction.

§. 37. Again, a certain greater proportion of water or watery fluids, than is found in these dry substances mentioned above (observeable in the green twigs and branches of trees, and other vegetables; and in the fresh arteries, veins, and other recent parts of animals) produces a sensible elasticity, easily to be brought into action; because the larger molecules or drops of the interspersed fluids by a lesser or weaker *nifus* of their extreme particles one to another, and to their respective centres, admit an easier change of figure in the bending or extension, and thereby gain a more sensible motion in their restitution. That is, by this greater proportion of fluids in their pores and vessels, they become more sensibly elastic. As in *Cor. Prop.* II.

§. 38. But if this proportion of fluids be farther increased, all these substances become soft and pulpy, and thereby lose their elasticity; because the interspersed molecules of the fluids are now so large, that the particles of their extreme surfaces, contiguous to the solid parts of the compound, are less attracted towards their centres, and therefore upon change of figure are incapable of restoring themselves. That is, by a redundant moisture their elasticity is lost, and they become soft; they fall into a degree of solution, or the lowest degree of fluidity. See *Prop.* VI. and VII.

§. 39. And if this proportion of fluids be yet more or greatly increased, the solid is completely dissolved, (see *Prop.* III. V. and VII.) its solid particles being repelled, or driven asunder by the interposition of a copious fluid, as by so many wedges succeeding one another, increasing in bulk, and impelled by attraction, the prime spring of motion in all solutions, fermentations and putrefactions; but as this opens a very large field of disquisition, which would lead us too far from the purpose of these Lectures, it must therefore be left to some other opportunity.

§. 40. Thus the seemingly contrary or repugnant properties of water and other fluids in cementing and dissolving, hardening and softening, as well as communicating elasticity to solids, are reconciled; as arising from the same principle of central attraction, producing different and even contrary effects, by its different degrees of force, in different proportions of the fluid.

§. 41. By which it also appears, that there is no such principle in nature, as a centrifugal power: but that repulse (at least in all these *phenomena*) ariseth from the principle of central attraction in the restitution to equilibration; and from the impenetrability of matter; and the superior *momentum* of an increased fluid, forced into action by the same attraction: and therefore that it is no natural principle, but a forced effect, which was to be proved. See *Prop.* III. IV. V. VI. VII.

Fig. 1.

A

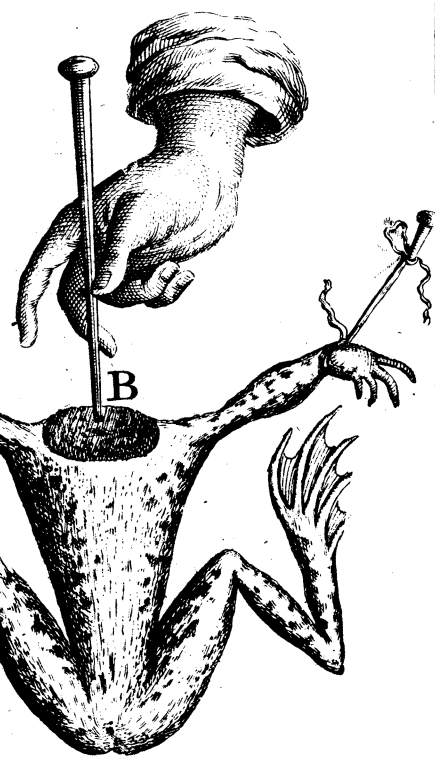
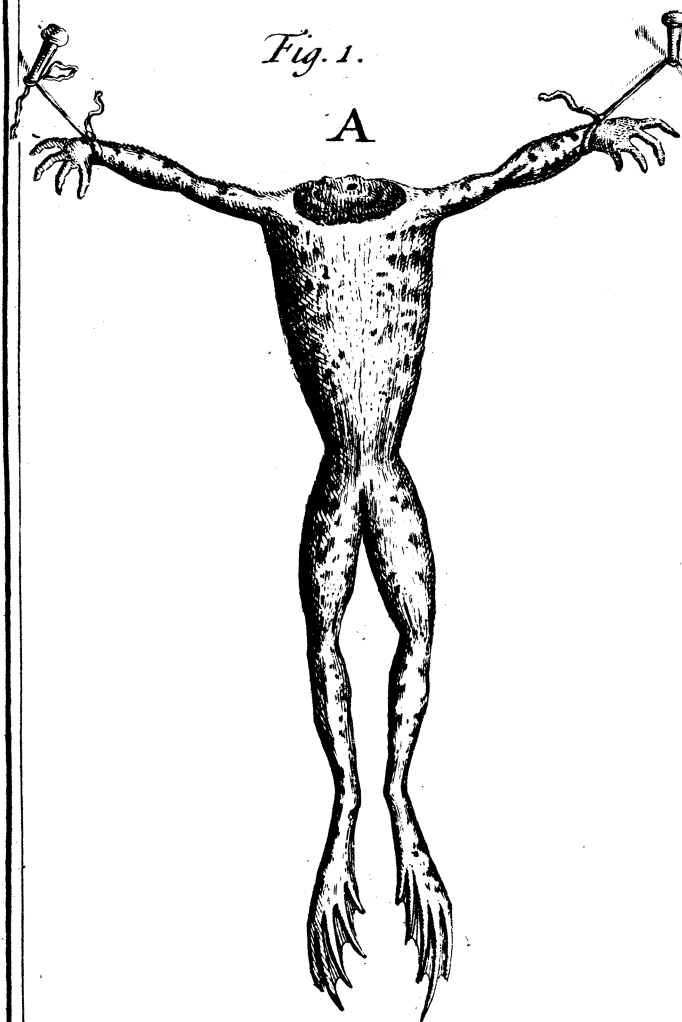


Fig. 2.

## LECTURE III.

**T**HIS Lecture, which is to be the last for this season, contains an explanation of the Vth Experiment, and a short abstract of a general scheme of muscular motion, which may lead us, without wandering from the purpose of these Lectures, through the whole animal œconomy : in which the principle of elasticity, which I have been endeavouring to explain in the former Lectures, bears so great a share, as it does indeed in other innumerable and surprizing *phenomena* of nature ; the centripetal power, from whence it ariseth, seeming to be, next to immaterial impulse, the inexhaustible source of all motion in the universe.

*The Manner, Explanation and Use of the Vth Experiment.*

*1st*, This Experiment is performed by suspending a live Frog by the fore legs in a frame, or in any other commodious manner, as in Tab. 3. fig. 1. when having cut off the head from the first vertebre of the neck with a pair of scissars, a small probe, the button at its extremity being first filed flat, is to be pushed very gently down upon the upper extremity of the *medulla spinalis*, in the first vertebre of the neck ; upon which the inferior limbs, which hung down loose, will be immediately contracted, as they appear in fig. 2. tab. 3. The same probe pushed gently through the hole of the occiput of the scull on the *medulla oblongata*,

*gata*, will make the eyes move, and sometimes the mouth to open.

2dly, The same being repeated at some small interval of a few seconds, succeeds for several times in the same manner; until the extremity of the spinal marrow be either pushed down too far out of the reach of the probe, or confused by it, which last effect appears soonest on the *medulla oblongata*: but after this the Experiment will not farther succeed, the compression then ceasing to be equal or uniform.

*Observations on this Experiment.*

*Obs. 1.* It must be observed, that this Experiment succeeds better in the summer months some time after the Frogs have spawned, than it does early in the spring, or in winter when those creatures are almost dead by cold, and want of food.

*Obs. 2.* The interval of a few seconds in repeating this Experiment on the same Frog, seems to be necessary for recovering the equality of the circulation, which was disturbed by the immediate preceding convulsion, as it throws the blood violently out of the muscles in the time of their contraction or systole, which cannot be restored immediately in such a languid state of circulation, as this Experiment must bring on; and as the assistance of the blood will appear by the following scheme to be necessary to muscular motion, where it is deficient, the motion must also be defective or imperfect, as it appears in repeating the pushes too quick.

*Obs. 3.* As the inferior process of the brain called the *medulla oblongata*, and its continuation called the spinal

spinal marrow, are only a continued or prolonged collection of the nerves arising from the brain and *cerebellum*; by this Experiment it appears, that the nerves contribute remarkably to muscular motion; and that their assistance in it is owing to the fluid they contain, I have endeavoured to prove, by shewing the non-elasticity of the nerves in the first Experiment.

*Obs. 4.* The motion here excited is in the muscles of voluntary or spontaneous motion, which are under the command of the will.

*Obs. 5.* The effect of the impulse by the probe is the same, which is or may be produced in these muscles by the mind or will; or is the very same in its manner as voluntary or spontaneous motion, and performed by mediation of the same instruments, to wit, the animal spirits, or fluid of the nerves, and the muscles of voluntary motion.

*Obs. 6.* The extremity of the probe applied in this Experiment being flat, cannot produce this effect by irritation, but by compression; and the compression of the pliable extremities of tubes full of any fluid, must depress or propel the contained fluid towards the lower or opposite extremities, with an increased degree of velocity. Therefore at least the beginning of this motion may be justly ascribed to a propulsion of a small quantity of the contained fluid, through these slender canals into the muscles, in which they terminate, with some greater degree of velocity, and in some greater quantity than usual. Whence we may conclude, that voluntary muscular motion in a living animal is begun in the same manner, by an impulse of the mind or will on the animal spirits through the nerves, into the muscles.

*Cor.*

*Cor.* And as the quantity of animal spirits propelled into the muscles in this Experiment must be supposed very small; it follows, that the waste of this fluid by moderate voluntary motion in life is very inconsiderable, or little more than what arises from the common course of the circulation, moderately promoted by easy exercise, and useful for health.

*Obs.* 7. In the following short abstract of a general scheme of muscular motion, the structure of a muscular fibre is supposed vesicular, with a reticular *plexus* of blood-vessels investing each vesicle; which is confirmed by an universal analogy in the structure of all the moving parts in the animal œconomy, visible in the heart, lungs, stomach, intestines, urinary bladder, &c. whose motions consist in an alternate systole and diastole. Therefore the nature and manner of the muscular motion produced in this Experiment must be the same, while the heart continues to beat, and the blood to circulate in the limbs, in the same manner, though not with the same force, as before the Experiment. Which will be farther explained in the following scheme.

*An Abstract of a general Scheme of muscular Motion. See Diss. de Struct. & Mot. Musc.*

**T**HE order of accounting for muscular motion consists in assigning, 1. The principles. 2. The immediate cause or causes. 3. The instruments. 4. The manner of action, or *modus*. 5. The effects of it.

1. The



1. The principles or sources of all motion whether natural or artificial, are only two; impulse, and centripetal power.

2. Original impulse, and therefore every new motion, must arise from some immaterial being, as its immediate cause. *Diff. de Struct. & Motu Musc. Cap. 1.*

3. Impulse, as the beginning of every new muscular motion, is in the power of the mind or will, which must therefore be an immaterial being. *Diff. de Struct. & Motu Musc. Cap. 2. 5.*

4. Centripetal power, or the power of contraction, is the most universal principle in nature, producing repulse; and is properly the elasticity of the instruments of muscular motion.

*Schol. 1.* Inquiries into the intermediate cause or causes of this universal centripetal power, of which elasticity is only one branch, are not to be dropt, or neglected; but after all our researches and discoveries we shall be forced at last to acknowledge, that at the origin of the chain of natural causes, in all its real or imaginary length, there must be an omnipresent and immaterial agent as the prime cause.

*Schol. 2.* In the mean time, in many *phænomena* of nature it is much to be doubted, whether that chain be so long as is generally imagined; and whether God himself be not the immediate, acting, ubiquitary cause of centripetal power; which seems to be the immediate cause of all the *phænomena* of nature; the indefinite variety of them appearing to arise only from the different structure of the machines or instruments, and other circumstances of action. And it is evident, that all those *phænomena*, which by some of the antient philosophers have been attributed to a *fuga vacui*,

*vacui*, arise from a perpetual *nifus* to equilibration, the ultimate aim of nature, and the immediate effect of this centripetal power.

And though this universal centripetal power was to be admitted as the *ne plus ultra* in the line of causes or principles, (which I do no ways pretend to determine) and was to be resolved into the immediate and ubiquitary agency of GOD as the prime mover; this would nevertheless be far from putting an end to all further disquisitions, or inquiries in natural philosophy; as some may have inadvertently apprehended: for there would be still an almost infinite work behind, for exercising all the faculties of the mind, in explaining the innumerable varieties of the *phenomena* or effects arising from this principle. We should still be far from knowing all its laws of motion, all the degrees of its force, and the indefinite variety of its directions in the innumerable productions of nature, with all their various structures; which would still remain the inexhaustible subjects of inquiry in natural philosophy; by unfolding of which, she would not only nominally, but really, become the mistress of all arts and sciences; the former being only imitations of the works and designs of nature, and the latter the doctrine or explanations of the same works, whether physical or moral. But to return from this digression.

5. The universal instrument of all animal motion is a MUSCLE. *Diff. Cap. 3.*

6. No other vessels are observed to enter into, or to make a part of the composition of a muscle, but nerves and blood-vessels; therefore a Muscle, or the compound instrument of all animal motion, must be made up of these only. *Diff. Cap. 4. & Conclus.*

7. The

7. The nerves are not elastic, but serve to convey an aqueous fluid, called the animal spirits, from the brain, *cerebellum*, or spinal marrow, to the muscles. *Diff. Cap. 5, 6.* Which fluid is the immediate subject of impulse, or the immediate instrument of the mind for beginning muscular motion. As appeared by Experiment V. made on a Frog.

8. The blood-vessels and blood are elastic; whence the centripetal power, or contraction and repulse in muscular motion. *Diff. Cap. 6.*

9. The external distribution of the nerves and blood-vessels to the antagonist muscles formerly exhibited in Tab. 2. fig. 1. shews, that each antagonist has its distinct nerve or nerves without communication; but the antagonist muscles communicate one with another by one common trunk of an artery, and one common trunk of a vein: so that they are like two antagonist scales *in æquilibrio*, over which the mind has a distinct power by distinct nerves for determining the animal spirits, and thereby the blood, to either side at pleasure, without affecting the other.

10. The internal disposition of these vessels in the composition of this instrument is taken from the universal analogy, visible in all the moving parts of the animal machine: to wit, the heart, lungs, intestines, urinary bladder, &c. wherein such a structure appears to the naked eye, as gives us the following Idea of the smallest muscular fibre, described in *Diff. Cap. 8.* that is, *a nervous fibre produced from its entrance into the muscle along or in the axis of each carnosus fibre, in the form of a chain of distensible vesicles, whose sides are covered with a net-work of elastic longitudinal and transverse blood-vessels; the extremities of all these nerves compacted forming the tendon,*

don, which being spread out or expanded again, forms the periosteum. See fig. 2. and 3. Tab. 2.

11. By the naked eye, or with the help of a microscope, this smallest muscular fibre appears of the same blood-red colour, and of the same shape or figure with the whole muscle, whence it is taken; and the whole muscle of voluntary motion is no more than a fascicle or bundle of such small muscular fibres: therefore its action can be nothing else, than the joint action of all these. *Introd. to Diff. page 1, 2.*

12. But the action of the whole muscle by Dr. Glisson's Experiment, appears to be only an alternate diastole and systole: and therefore, by what has been said in the last paragraph, there must be such a diastole and systole alternately in each of the small carnos fibres of which it is composed. *Diff. Exp. 1. Cap. XI.*

13. And by the Vth Experiment already mentioned on a Frog, it appears, that a very strong muscular motion may be easily excited by a very slight impulse through the nerves. As in Experiment V.

14. But such an easy production of motion is not conceiveable, without the nicest equilibration of all parts of the machine moved.

15. Therefore a statical equilibration of the antagonist muscles of each limb is described, and delineated in *Diff. Tab. 4.* shewing the equilibration of their elasticity.

16. And an hydrostatical equilibration of the fluid of the nerves is described and figured in *Diff. Tab. 5.*

17. Now equilibrated bodies may be easily moved, by adding or diminishing the least imaginable force of either side; but if what is taken from one be added to the other, the *momentum* of the motion will be doubled, without the loss or expence of what is taken

taken away, *Diff. Theor.* 19, 20. which is the case in muscular motion, in its progress from utmost extension to final contraction; as will appear in the sequel.

18. We are now to shew how easily a very strong motion may be excited, and carried on in a machine of this fabric, whose parts are in so just and accurate an equilibration.

19. Previous to which it may be necessary to remove the following objection or difficulty, which occurs in *Diff. Cap.* 10. where it appears, that the power of absolute elasticity in the muscles greatly exceeds the utmost force of impulse in the power of the mind. But the statical equilibration of that elasticity, and the hydrostatical equilibration of the nervous fluid mentioned before, take off all resistances, that would else be in the way of that impulse, by which it becomes sufficient for the purpose, so as to be able to begin muscular motion; which is carried on in the following manner.

20. The whole progress of muscular motion is from the state of utmost extension, through the states of relaxation, equilibrium, complete inflation or diastole, to the state of ultimate contraction or systole. In all which courses from the first term to the last each vesicular fibre shortens its axis; and therefore draws the limb affixed into flexion, or extension, at the pleasure of the mind. *Diff. Tab.* 4.

21. The mind can act upon the muscular fibres in any state, but that of ultimate contraction, which is the termination of the progress of muscular motion; as the beginning of it is from the state of utmost extension. *Diff. Cap.* 10.

22. In the state of utmost extension then, the longitudinal capillary blood-vessels on the surface of each

each vesicle in the fibres must be extended, and therefore their transverse diameters must be lessened: that is, these vessels thereby become straiter, and the circulation in them therefore more difficult; and in this state also the transverse blood-vessels of each vesicle will be forced into serpentine flexures, which must render the passage of the blood through them still more difficult. *Diff. Cap. 9.*

23. In this, and all other states of the antagonist muscles, both the statical and hydrostatical equilibration, mentioned above, take place to such a degree, as to remove all resistances, that would else be in the way of any supervening impulse. *Diff. Cap. 10.*

24. Therefore if the mind impels but a very little more of the nervous fluid than usual, through the slender tubes of the nerves, into these extended vesicles, they will be uniformly dilated as in the known Experiment of the Water-bellows. *Diff. Cap. 9. and Th. 22.*

25. By this distension of the vesicles their axes being shortened, and their diameters lengthened, the longitudinal capillary vessels on their surface must be shortened, and thereby their diameters enlarged; and the serpentine flexures of the transverse vessels will be extended; which in both kinds will lessen the resistance they gave to the transit of the blood, which both by the diastole and systole of the arteries is continually urged on to its passage through them; and being thus facilitated, every globule of blood in its progress, by endeavouring to fly off by the tangents of these vessels and vesicles, tends to expand them more, and thereby opens the way for the further and easier influx of the nervous fluid; to which the blood-vessels contribute as so many elastic levers acted upon by the  
blood

blood in its progress. Thus by the assistance of these three powers, of the nervous fluid, the blood, and blood-vessels, the progress from extension to inflation or diastole of the vesicles is made, with such a degree of celerity as the will commands. *Diff. Cap. 9.*

26. The muscle is at that time tumid and enlarged by the afflux of the nervous fluid and blood, which increases its bulk.

27. The mind may keep up this inflation, as long as it pleases, only by impelling constantly such a small quantity of the nervous fluid into the distended vesicles, as is sufficient to supply the usual expence of them in their common course.

28. But if the mind desists to send in this recruit, or suspends it, then these circular or arched elastic vessels now turgid with elastic blood, whose areas have been thus forcibly enlarged, endeavour to contract themselves every way towards the centres of their areas, which are the centres of the vesicles; and, the mind giving no resistance, this *nifus* takes place to the complete contraction of each fibre; by which the limb affixed is brought into complete flexion or extension, according as this or the other antagonist has been acted upon. *Diff. Cap. 9.*

29. In this state the whole muscle becomes shorter, and less in all its dimensions; harder and paler by expulsion of a great part of its fluids through the veins towards the heart, and through the extremities of the nerves into the tendon and *periosteum*. And such are the visible *phenomena* of this and all other moving parts of the animal machine.

30. It may be imagined, that such interruptions of the course of the blood in the capillaries of the arteries and veins, and such uncertain subsultory changes in the figure

figure of the parts as have been described, might interrupt the regular circulation of the blood, and thereby disturb the motion of the heart; which is not observed to happen by moderate exercise. But this difficulty is removed by considering, that the whole is carried on in extensile and distensile blood-vessels, communicating one with another, as in Tab. 2. fig. 1. and therefore what cannot be received into one is immediately communicated to, and easily received by the other, and by it forwarded in its return to the heart, in the same time and quantity, as if the passages through all the vessels were equally open, and passable. Therefore though an acceleration does arise in all exercises, yet an irregularity of the circulation in a healthy person is not observed to happen by any degree of exercise.

What I have here briefly recited, I have at large endeavoured to explain in a *Dissertation* on this subject lately published, with several figures annexed for illustration of the whole; by which, I hope, the principles, causes, instruments, manner of action, and effects, in which the *ratio* of muscular motion consists, have been pointed out from anatomy, mechanics, hydrostatics, observations and experiments. To which, for the sake of brevity, I have every-where referred.

The proof and illustration of this general scheme will appear in the application of it, for explaining the various functions of the animal œconomy; which may naturally become the subjects of some future inquiries towards answering the intention of the worthy Founder of these Lectures.



---

# EXPLANATIONS

## OF THE

# TABLES.

---

### TABLE I.

#### FIGURE I.

**C**ONTAINS a nerve, artery and vein of an human subject, which before excision were all of equal length with a piece of twine applied to measure them.

*A.* The nerve after excision, continuing of the same length as it was in the body ; to wit, equal to the twine *B*.

*B.* The twine or common measure of all the vessels before excision.

*C.* The artery, which in the body was of the same length with the nerve and twine ; but being cut out and left to itself shrinks, or contracts, to the

loss of  $\frac{2}{8}$  of its length; as those of Dogs lose about  $\frac{3}{8}$ .

**D.** The vein, which was equal to the nerve and twine in the body; but being cut out and left to itself shrinks, or contracts as much as the artery, though not with the same degree of force.

Hence it appears that the arteries and veins are evidently elastic, and that the nerves have not the least apparent elasticity. See *Exp.* I. Lect. I.

FIGURE 2.

**A.** The *Rose of Jericho*, expanded by being steeped two hours in water, weighing 13 drachms, and resembling its state of growth in the ground.

FIGURE 3.

The same dry and contracted; weighing 7 drachms and a few grains.

TABLE II.

FIGURE I.

Contains the antagonist muscles of an human arm, placed at a little more than their natural distance, with the nerves, arteries, and veins distributed to them in their natural situation and order.

**A. A. A.** The muscle *biceps*, one of the flexors or benders of the cubit or fore-arm.

**B, B, B.**

*B.B.B.* The internal brachial muscle, another flexor or bender of the fore-arm.

*C.C.C.C.* The external brachial muscle called *triceps*, an extensor of the fore-arm.

The muscle called *anconaeus*, another extensor of the fore-arm, is hid here.

*D.* The common trunk of the branchial artery, distributing the blood by its branches to all these antagonist muscles on each side of the arm; red, expressed by the lines thus ||| as in Heraldry.

*E.* The common trunk of the vein, through which the blood brought back from the muscles on each side returns towards the heart; blue, expressed as in Heraldry thus ≡.

*F.* The trunk of the nerve peculiar to the flexors of the fore-arm, whose branches are peculiarly distributed to these flexors only, but not to the extensors; white.

*G.G.* Two trunks of nerves peculiar to the extensor muscles of the fore-arm, whose branches are peculiarly distributed to these muscles only, but not to their antagonists the flexors; white.

The number of the branches of these several vessels, and the manner of their distribution and insertion into these muscles, appear in the figure. I need only to observe, that the antagonist muscles, that is, the muscles of each side communicate one with another by their blood-vessels, but not by their nerves.

# [ III ]

By the help of this figure the mechanical manner of muscular motion delivered in Lecture III, will be easily understood.

## FIGURE 2.

*A.* Represents a muscular fascicle, or small part of a muscle, macerated in water, and carefully separated longitudinally from the rest of the muscle, with its tendinous extremities; expressing together the figure of the intire muscle, as mentioned §. 11. Lect. III. and at greater length in *Cap. VII. §. 5. Diff. de Struct. & Mot. Musc.* and *Introd. §. 2. and 18.*

*B, B, B, &c.* The carnosus red fibres drawn asunder, that the nervous white *fibrillæ* or fillaments distributed to them may better appear.

*C, C, C.* The nervous white fillaments, entering the carnosus fibres at angles more or less acute.

*D, D.* The tendinous extremities of the muscular fascicle; being the nerves and nervous membranes of each muscle or part of a muscle collected, and compacted to the firmness of a tendon; whence being again expanded, it is justly called the *aponeurosis*; and being farther continued over and into bones, is called their *periosteum*.

*F, H, G.* Shew the directions and distributions of these processes of the nerve, artery, and vein to the muscular fascicle, simular to their directions and distributions to the whole muscle.

This

This figure is the same with the next following; excepting that in this the small nervous vesicles in each carnosus fibre are supposed to be covered by the blood-vessels.

### FIGURE 3.

*A.* Shews the angle of insertion of the nerve into this fascicle, as into the whole muscle, with the direction and distribution of its branches into the muscular vesicles.

*B, B, B.* The chains of the muscular vesicles, supposed to lie in the direction of the axis of each carnosus fibre, and to be inflated or distended by the influx of the nervous fluid, at the command of the will in the diastole of the muscle. See *Diff. de Struct. & Motu. Musc. Cap.* VIII. §. 2, 4, 5, 7, 8. and *Abstr.* in Lect. III.

This verficular structure of the smallest muscular fibre, pointed out and confirmed by a similar structure in all the visible moving parts of the animal œconomy, may be justly inferred from the plain analogy of nature, which is always similar to itself; by which it will be easy to understand what is said of the general muscular structure in *Diff. Cap.* VIII. and of the manner of muscular motion *Cap.* IX. and more compendiously in the *Abstract* of that general scheme in Lect. III.

# TABLE III.

## FIGURE I.

*A.* A live Frog, the head being cut off, hanging by the fore-legs without motion.

## FIGURE 2.

*B.* The same Frog, whose inferior limbs, which hung loose and free, are brought into a strong and complete contraction by a very slight impulse with the button end of a probe, on the upper extremity of the spinal marrow; the end of the probe being filed flat and smooth for that purpose. See *Experiment V.*

---

### ERRATA.

Left. II. Page 25. l. 19. *for* intermediate, *read* immediate.

Left. III. Page 41. l. 15. *for* of muscular motion, *read* in muscular motion.

---

Printed for T. WOODWARD, at the *Half-Moon*, between the *Two Temple-Gates* in *Fleetstreet*; and C. DAVIS, the Corner of *Pater-noster-row*, next *Warwick-lane*; PRINTERS to the ROYAL SOCIETY. M.DC.CCCCXXXIX.

---

*Just published, and sold by* Tho. Woodward *at the*  
Half-Moon *between the* Temple-Gates *in* Fleet-  
street, *and* C. Davis *in* Pater-noster-Row, *Printers*  
*to the* ROYAL SOCIETY,

# DISSERTATIO

DE

Structura & Motu MUSCULARI,

AUCTORE

ALEXANDRO STUART, M. D.

Serenissimæ CAROLINAE, Mag. Brit. &c. nuper  
Regin. Med. Ord. Coll. Reg. Med. Lond. & R. S. S.

*Opimonum commenta delet dies, naturae judicia tonfirmat.*

Cic. de Nat. Deor. Lib. II. cap. 2:

---